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TRANSACTIONS

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ERRATA.

Page 2, sixth line: read equilateral triangle.

Page 2, fourteenth line: for *isoceles*, read equilateral.

Page 8, eighth line from bottom: for *liquidation*, read liquation.

Page 9, ninth line: for *Sn.*, 2.5, read Sn. 0.5.

Page 11, nineteenth line: for $4t$, read $3t$; and for 50, read 55.

Page 11, twenty-first line: for 50, read 55.

Page 11, twenty-second line: for 12.5, read 18.

Page 238, fifth line: insert the figures 242, so that it will read (see p. 242).

Page 241, omit lines 17, 18 and 19, and in their place read: WILLIAM R. HUTTON.—The data from which the table on the following page has been prepared have been gathered from various sources.

Page 241, twentieth line: for *flow discharges*, read flood discharges.

Page 242, second line of table: for 84, read 8.4. Third line of table: for 131, read 13.1.

Page 250, first line: for *J. J. R. Cross*, read J. J. R. CROES.

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CCXIV.

(Vol. X.—January, 1881.)

THE STRONGEST OF THE BRONZES.

A NEWLY DISCOVERED ALLOY OF MAXIMUM STRENGTH.

By ROBERT H. THURSTON, Member of the Society.

READ JANUARY 5TH, 1881.

The writer, when conducting a series of investigations of the properties of the copper-tin-zinc alloys, in the Mechanical Laboratory of the Stevens Institute of Technology, by request of a committee of the U. S. Board, organized under an act of Congress secured by a request of the American Society of Civil Engineers, and of gentlemen taking an interest

in that enterprise, was led to devise a method of planning that research* and a system of recording data that has since led to the discovery of alloys of probably the maximum possible strength obtainable by any combination of the elements studied.

This system is briefly the following :

In any triangle, B, C, D, Fig. 1, let fall perpendiculars from the vertices to the opposite sides, as for example, $\overline{CE}$. From any point within the triangle, A, let fall perpendiculars $\overline{AG}$, $\overline{AH}$, $\overline{AF}$, and draw $\overline{AB}$, $\overline{AC}$, $\overline{AD}$ to the vertices, thus obtaining three triangles, $\overline{ABD}$, $\overline{ABC}$, $\overline{ACD}$; their sum is equal to the area of the whole figure $\overline{BCD}$.

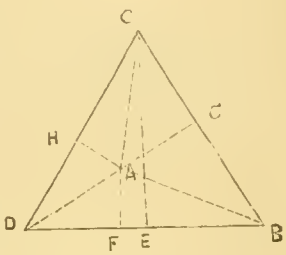

Fig. 1.

Now we have, since the triangle is isoceles, and

$$\frac{\overline{CE} \times \overline{BD}}{2} = \frac{\overline{AF} \times \overline{BD}}{2} + \frac{\overline{AG} \times \overline{BC}}{2} + \frac{\overline{AH} \times \overline{CD}}{2},$$

$$\overline{CE} \times \overline{BD} = (\overline{AF} + \overline{AG} + \overline{AH}) \times \overline{BD};$$

and

$$\overline{CE} = \overline{AF} + \overline{AG} + \overline{AH}$$

which follows wherever the point A may be situated ; it is true for every point in the whole area $\overline{BCD}$. Assuming the vertical $\overline{CE}$ to be divided into 100 parts; then $\overline{AF} + \overline{AH} + \overline{AG} = 100$ and $\frac{\overline{AF}}{100}, \frac{\overline{AH}}{100}, \frac{\overline{AG}}{100}$, measures the relation of each of the altitudes of the small triangles to that of the large one.

But we may now conceive the large triangle to represent a triple alloy of which the areas of the small triangles shall each measure the proportion in which one of the constituents enters the compound, and

$$\overline{BCD} = 100 \text{ per cent.} = \left(\frac{\overline{AF}}{100} + \frac{\overline{AG}}{100} + \frac{\overline{AH}}{100}\right) \overline{BD}, \text{ or}$$

$\overline{CE} = 100$ per cent. $= \overline{AF} + \overline{AG} + \overline{AH}$ per cent. and the altitude of each small triangle measures the percentage of some one of the three elements which enter that alloy which is identified by the point. Thus

*On a new method of planning Researches, &c., by R. H. Thurston, Proc. Assoc. for Advancement of Science. Vol. XXVI.

every possible alloy is represented by some one point in the triangle $\overline{B\,C\,D}$, and every point represents and identifies a single alloy, and only that. The vertices B, C, D, in the case to be here considered, represent respectively, copper = 100, tin = 100, zinc = 100. Thus, having determined a method of studying all possible combinations, the writer next prepared to examine this field of work in the most efficient and complete manner possible, with a view to determining, by the study of a limited number of all possible copper-tin-zinc alloys, the properties of all the numberless, the infinite, combinations that might be made, and with the hope of detecting some law of variation of their valuable qualities with variation of composition, and thus ascertaining which were the most valuable for practical purposes.

With this object in view, the triangle laid down to represent this research, was laid off into concentric triangles, Fig. 2, varying in altitude by an equal amount—10 per cent.—on which were laid out the following series of alloys :

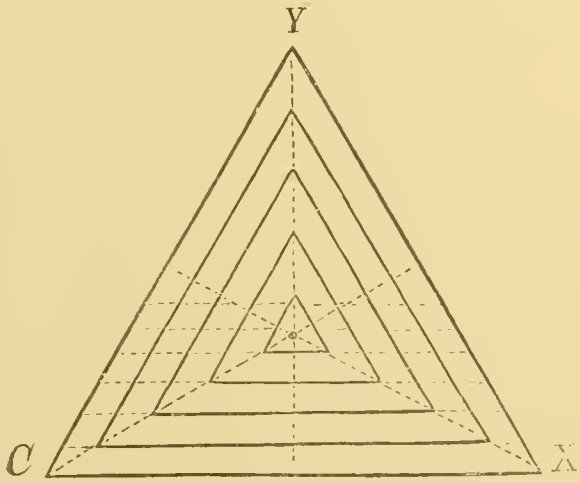

Fig. 2.

COPPER-TIN-ZINC ALLOYS.—THURSTON.

COPPER.	ZINC.	TIN.	COPPER.	ZINC.	TIN.
10	10	80	30	40	30
10	20	70	30	50	20
10	30	60	30	60	10
10	40	50	40	10	50
10	50	40	40	20	40
10	60	30	40	30	30
10	70	20	40	40	20
10	80	10	40	50	10
20	10	70	50	10	40
20	20	60	50	20	30
20	30	50	50	30	20
20	40	40	50	40	10
20	50	30	60	10	30
20	60	20	60	20	20
20	70	10	60	30	10
30	10	60	70	10	20
30	20	50	70	20	10
30	30	40	80	10	10

These alloys were first all tested in the Autographic Recording Machine, and their strain-diagrams were carefully studied. It was at once found that only a very few were of great value, and that the alloys represented by that part of the field lying on the tin-zinc side of a line running from copper = 70, tin = 30, zinc = 0, to the point copper = 40, zinc = 60, tin = 0, were too soft or too brittle and weak to be of value. The research was now restricted to the examination of alloys lying nearer the point copper = 100, *i. e.*, the upper vertex of the triangle as seen in the figure, and all such alloys were tested by tension, compression and torsion, and by transverse stress.

The results were quite accordant, and the quality of the metal could be judged as well by one set of data as by another, although, as a matter of course, the strain-diagram, obtained automatically, gave the best idea of the nature of the metal where the observer had been accustomed to that method. When the figures thus obtained had been entered on the triangular map, lines of equal strength, of equal ductility, or of equal resistance could be drawn, as in topographical work lines of equal altitude are drawn, and the map became thus a useful representation of the valuable qualities of all possible alloys.

Figure 3 represents such a map* of all copper-tin-zinc alloys. The scale of altitudes is obtained by considering the relation of tension to torsion resistance as 25 000 pounds per square inch (1 758 kilograms per square centimeter) for each 100 foot-pounds (13.82 kilogrammeters) of torsional moment for the standard test-specimen, which specimen was turned to a standard gauge, and made $\frac{5}{8}$ inch (1.84 cm.) diameter and 1 inch (2.54 cm.) long in the cylindrical part exposed to strain.

These facts, as determined experimentally, were subsequently still better exhibited by another method devised by the writer for class illustration ; thus :

Upon a triangular metal base, laid off as above, erect a light metallic staff by drilling a hole for its support at each point laid down as representative of an alloy tested; make the altitude of each of these wires proportional to the strength of that alloy. There is thus produced a forest of wires, the tops of which are at elevations above the base-plane proportional to the strengths of the alloys studied. Similar constructions may be made to represent the elasticity, the ductility, or any other property of all these alloys.

Next fill in between these verticals with clay or, better, with plaster, and carefully mould it until the tops of all the wires are just visible, shining points in the now smooth surface of the model. The surface thus formed will have a topography characteristic of the alloys examined, and its undulations will represent the characteristic variations of quality with changing proportions of the three constituents.

This was made for the writer, and was cast in an alloy which is the subject of this paper, the plaster cast made as above being used as a pattern, and this cast is used in lecture-room illustration, and is supplied where demanded to other institutions.

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* Reports of U. S. Board testing Iron, Steel, &c. Washington. 1878—1881.

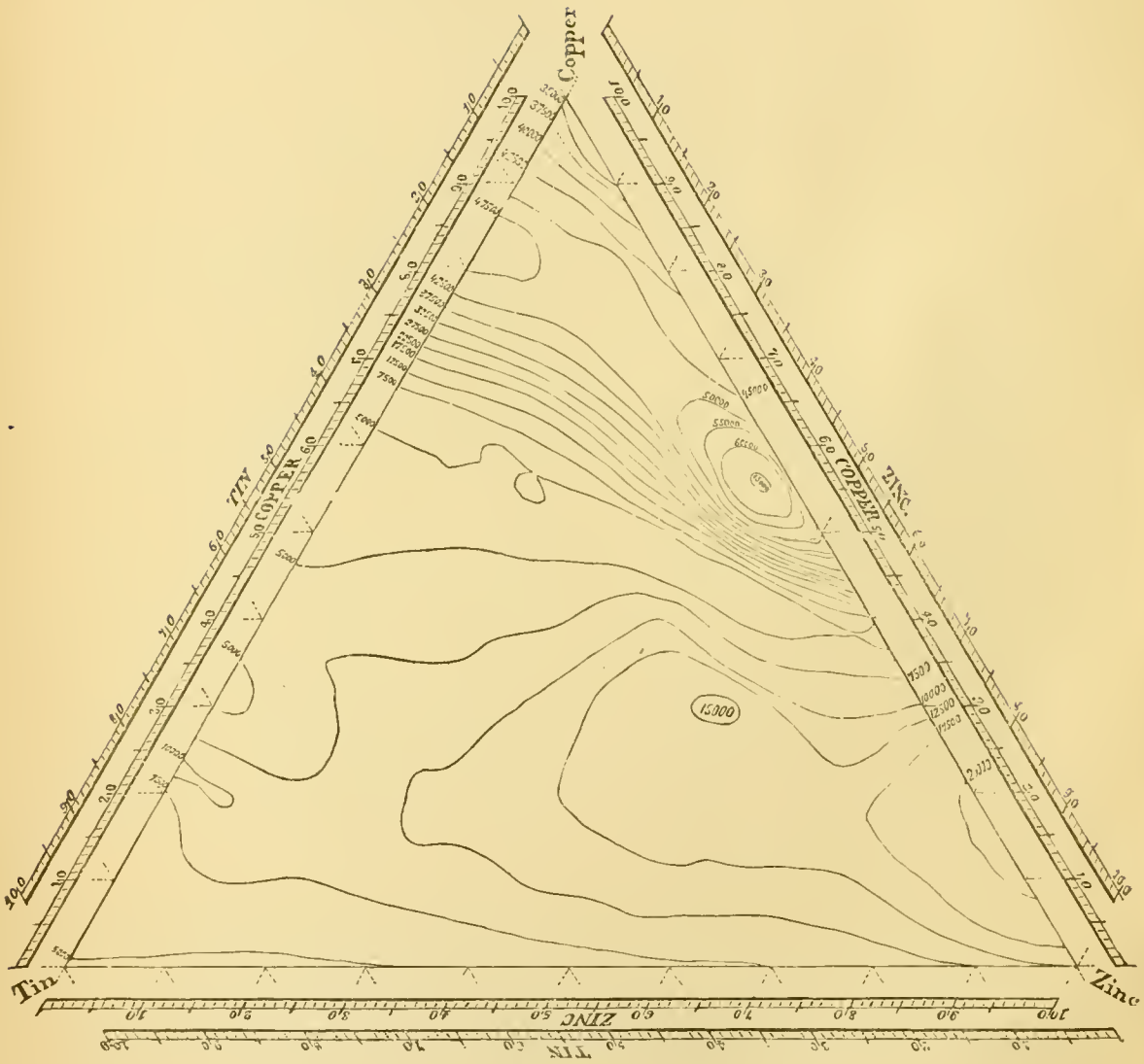

Fig. 3.

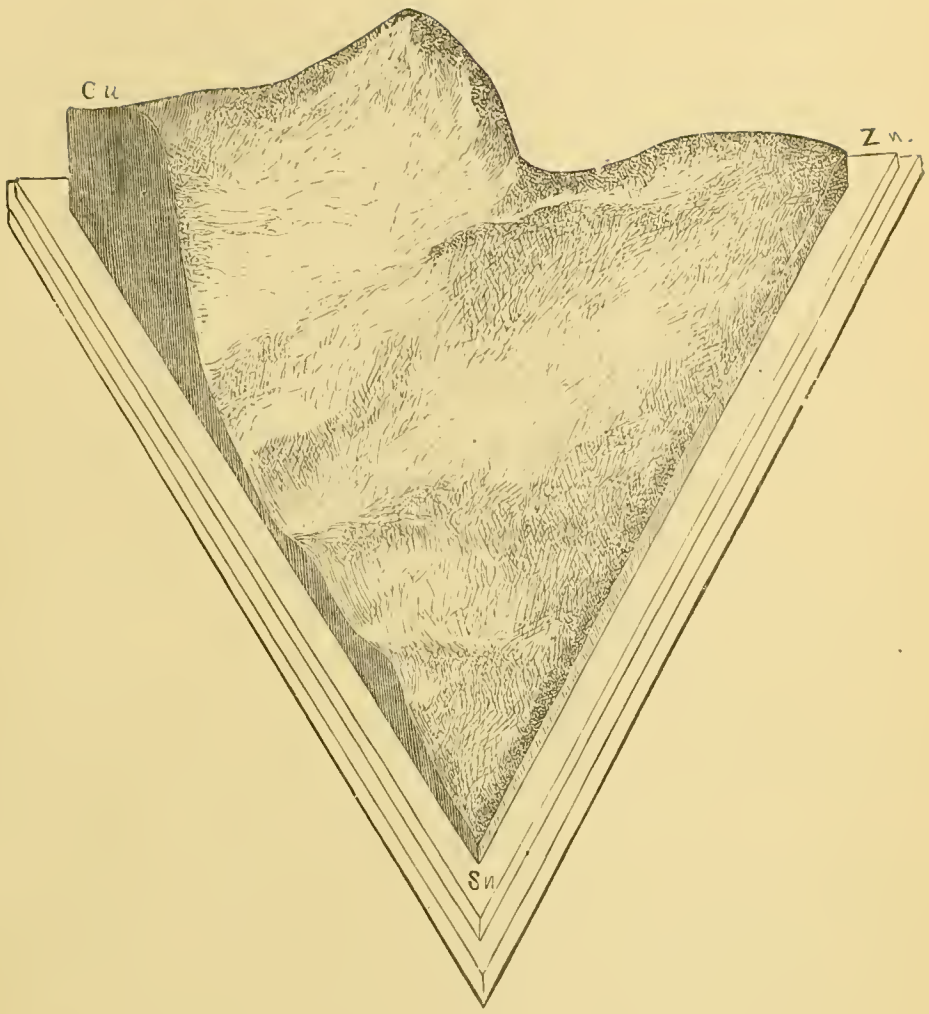

Fig. 4.

Figure 4 is a good representation made from a photograph of the model for the American Association for the Advancement of Science.*

The remarkable variations of quality here so strikingly shown, naturally attracted the attention of the writer, as of every one to whom he exhibited these models and maps, and a further investigation was made.

The alloys studied were originally intended to furnish data during a preliminary research that should serve as a guide in a later and more complete study of this important and intensely interesting field of investigation; the plan was never completely carried out, in consequence of

* Proceedings, 1878, Vol. XXVI.

the failure of Congress to make needed appropriations and the consequent demise of the Board.* These alloys were purposely made precisely as the brass-founder is accustomed to make them, without other precautions than those observed by every good founder, and without using any of the deoxidizing fluxes—as phosphorus—that would have been experimented with later. The intention was to make this first survey of the field rapidly, inexpensively, and in such a manner as to give a good idea of the best way to pursue the later and much more exact research, while giving the founder a good idea of the nature of the metals that he turns out in every day work.

The data obtained were consequently exceedingly variable, and the results of this work indicated as one, and not the least valuable, of deductions from it that the same alloy, and especially where the proportion of copper is great, may give very different figures when tested according as it is more or less affected by the many circumstances that influence the value of all brass-foundry products.

Some of the variations in the model are probably due to such accidental circumstances, and quality shown by any individual alloy is representative of a mean which the writer was often compelled to deduce from observations which were quite discrepant. But allowing for all such minor variations, it is evident at a glance that the alloys of maximum strength are grouped, as shown in Figures 3 and 4, about a point not far from copper = 55, zinc = 43, tin = 2. This point is encircled in the map, Figure 3, by the line marked 65 000 pounds per square inch (4 570 kilogs. per sq. cm.) tenacity, and is represented on the model, Figure 4, by the peak of the mountain seen at the farthest side—the copper-zinc side as drawn.

This is obviously the strongest of all bronzes, and an alloy of this composition, if exactly proportioned, well melted, perfectly fluxed, and so poured as to produce sound and pure metallic alloy, with such prompt cooling as shall prevent liquidation, is the strongest bronze that man can make.

The writer finally made this alloy, and of it constructed the model represented in the last figure. It is a close-grained alloy of rich color, fine surface, and takes a good polish. It oxidizes with difficulty, and the surface then takes on a pleasant shade of statuary bronze green.

* An effort which has been recently made to re-establish the Board has not yet (December, 1880.) met with success.

Testing it, it was found to have considerable hardness, but moderate ductility, though tough and ductile enough for most purposes; it would forge if handled skillfully and carefully and not too long or too highly heated, had immense strength, and seemed unusually well adapted for general use as a working quality of bronze. In composition, however, it is seen to be a brass, with a small dose of tin.

The alloy made as representing the best alloy for purposes demanding toughness as well as strength contains less tin than the above composition. Cu., 55; Sn., 2.5; Zn., 44.5.

It had a tenacity of 68 900 pounds per square inch (4 841 kilogs. per sq. cm.) of original section, and 92 136 pounds (6 477 kilogs.) on fractured area, and elongated 47 to 51 per cent., with a reduction to from 0.69 to 0.73 of its original diameter.

No exaltation of the normal elastic limit was observable during tests made for the purpose of measuring it if noted. This alloy was wonderfully homogeneous, two tests by tension giving exactly the same figure 68 900. The fractured surface was in color pinkish yellow, and was dotted with minute crystals of alloy produced by cooling too slowly. The shavings produced by the turning tool were curled closely, like those of good iron, and were tough and strong.

The strain-diagrams from the autographic machine are shown in *fac simile* and of full size in the accompanying Plate 1. Their tenacity, as estimated from their resistance to torsion, is nearly equal to that determined by direct experiment, and the four samples tested 1 001 *A*, *B*, *C*, *D*, have given strain-diagrams that are all nearly precisely alike. They exhibit an elastic limit, *e*, at about $\frac{2}{3}$ their ultimate resistance, and just about the same as a piece of excellent gun bronze (Cu.90; Sn. 10 per cent.), 1 252 *A*, the strain-diagram of which lies beside them in dotted line. Their elastic resistance, which is measured by the area of the curve up to *e*, is superior to that of the gun bronze, and their elastic range is seen to be greater on inspection of the "elasticity lines," *e′ e′*. In ductility they excel 1 252 *A*, but not greatly, as is seen by comparing 1 001 *A* with 1 252 *A*. Their toughness is shown by the great area and the altitude of the curve; their excellence of quality is also shown by its smoothness of outline. The homogeneousness of structure is exhibited by the similarity of the diagrams and by the smoothness of the bend at *e*, which marks the elastic limit.

At f is a depression of the normal line of elastic limits produced by 17 hours intermission of distortion under the load there carried. This slight depression marks this alloy as one of the "tin class."

Diagram 1252 B is given by a very fine gun bronze; 1001 x is an hypothetical diagram, such as would be produced were the alloy here described so carefully fluxed and cast as to exceed in strength the unfluxed alloys actually tested, 1001 A, B, C, D in as great a proportion as 1252 B excels 1252 A. The diagram 1001 y would be produced were it possible to so far improve this alloy as to cause it to excel 1252 A as greatly as No. 1001 actually did excel the gun bronze made under similar conditions in this preliminary rough work. No. 1004 A is copied to exhibit the immense superiority of the alloy 1001 to one but little removed from it and which is considered by some brass founders an excellent composition.

It is impossible to say, without direct test, to what extent the alloys shown in figures 3 and 4 may be improved by special methods of working, and by more perfect fluxing than is usually secured in the foundry. This was to have been the subject of the next investigation; the ground had been cleared and the valuable alloys identified, and the work planned could have been rapidly and satisfactorily done had the opportunity been allowed. But from what can be gathered by the experience acquired the writer is inclined to suppose that careful mixture, thorough fluxing with phosphorus or other deoxidizing element, casting under pressure, rapidly cooling, and finally cold-rolling or cold pressing as practised by Dean,* copper-tin-zinc alloys, containing not to exceed $z + 3t = 30$ per cent. could be given a strength exceeding by 50 per cent. that obtainable under the ordinary conditions met with in the brass foundry. During the writer's experiments the copper used had a tenacity, as cast in small bars, of but one-half that obtained by Mallett, who fluxed out the oxygen more completely. Similarly, in these preliminary trials, gun bronze broke at two-thirds the figure obtained frequently in making ordnance.

Alloys rich in copper receive most benefit by such special treatment.

The writer has found that ordinary bronze, composed of copper and tin, may be taken with rough approximation to accuracy as having a tenacity, as cast in the ordinary course of a brass founder's business, of

* On the Mechanical Treatment of Metals; by R. H. Thurston; Metallurgical Review. 1877.

about—

$$T_c = 30\,000 + 1\,000\ t;$$

where t is the percentage of tin, and not above 15 per cent. Thus gun bronze can be given about $30\,000 + (1\,000 \times 10) = 40\,000$ pounds per square inch, if well made. In metric measures

$$T_c^1 = 2\,109 + 70.3\ t,$$

giving for good gun-metal $2\,109 \times 703 = 2\,812$ kgs. per sq. cm.

For brass (copper and zinc) the tenacity may be taken as

$$T_z = 30\,000 + 500\ Z;$$

where the zinc is not above 50 per cent.; and

$$T_z^1 = 2\,109 + 35.15\ Z.$$

Thus copper 70, zinc 30, should have a strength of $30\,000 + (500 \times 30) = 45\,000$ pounds per square inch, or $2\,109 + (35.15 \times 30) = 3\,165$ kilogrames per square centimeter.

Referring once more to figures 3 and 4, it is seen that a line of maximum elevation crosses the field marking the crest of the mountain in Figure 4, of which the "maximum bronze" is the peak. This line of valuable alloys may be practically covered by the formula :

$$M = z + 4\ t = \text{Constant} = 50,$$

in which z is the percentage of zinc, and t that of tin. Thus a maximum is found at about $t = 0$, $z = 50$, while the other end of the line is $z = 0$, $t = 12.5$.

Along this line the strength of any alloy should be at least

$$T_m = 40\,000 + 500\ z.$$
$$T_m^1 = 2\,812 + 35.15\ z.$$

Thus the alloy $z = 1$, $t = 18$ will also contain copper $= 100 - 19 = 81$ and this alloy cu. 81, zn. 1, sn. 18 should have a tenacity of at least

$$T_m = 40\,000 + (500 \times 1) = 40\,500 \text{ lbs. per sq. in.}$$
$$T_m^1 = 2\,812 + (35.15 \times 1) = 2\,847 \text{ kgs. per sq. cm.}$$

The alloy: cu. 60; zn. 5; sn. 16; should have at least the strength

$$T_m = 40\,000 + (500 \times 5) = 42\,500 \text{ lbs. per sq. in.}$$
$$T^1_m = 2\,812 + (35.15 \times 5) = 2\,988 \text{ kgs. per sq. cm.}$$

while the alloy *z*, 50; sn, 2; cn, 48; should give, as a minimum per specification:

$$T_m = 40\,000 + (500 \times 50) = 65\,000 \text{ lbs. per sq. in.}$$
$$T^1_m = 2\,812 + (35.15 \times 50) = 4\,570 \text{ kgs. per sq. cm.}$$

These are rough working formulas that, while often departed from in fact, and while purely empirical, may prove of real value in framing specifications. The formula for the value of T_m fails with alloys containing less than 1 *per cent. tin* as the strength then rapidly falls to $t = 0$.

The improvement that may be expected to follow special treatment of some, and probably nearly all the more valuable of these alloys, may be inferred from the fact that Mr. S. B. Dean, in 1869,* increased the tenacity of cast gun-bronze from 27 230 to 41 471 pounds per square inch (1 915 to 2 915 kilogs. per sq. cm.) by cold-working, and General Uchatius, who introduced the Dean process in Austria, by chilling, increased the strength of his "steel-bronze" from 35 092 pounds per square inch (2 260 kilogs. per sq. cm.), to 43 310 pounds (3 050 kilogs.);† the elastic limit remaining, however unchanged at 5 680 pounds per square inch (400 kgs. per sq. cm). This metal then cold-rolled by the Lauth method of Jones & Laughlin's, rose in tenacity to 71 937 lbs. with an elastic limit at 24 140 (5 066 and 1 700 kilogs. per sq. centimetre). This was the regulation alloy: copper, 90; tin, 10. When the tin was increased to 12 per cent. the alloy was too hard to roll.

Colonel Rosset, of the Italian army, repeated Dean's work and extended it with the same result.‡

On the copper side of the maximum point on our map and model of

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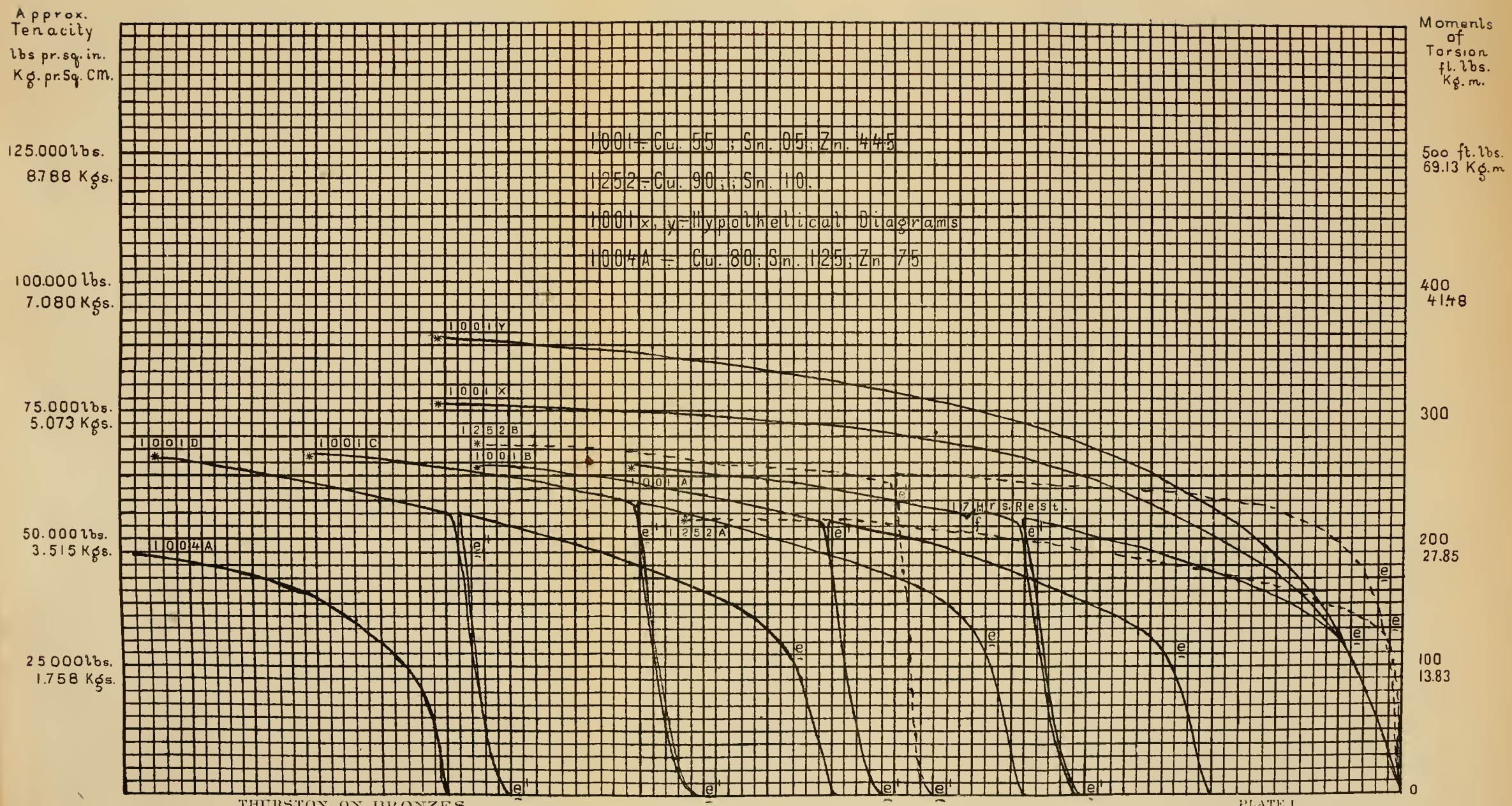
* Ordnance Notes, No. XL, p. 255.

† Report on Manufactures and Machinery at Vienna, 1873; R. H. Thurston: p. 326.

‡ Resistenza dei Principali Metalti; Torino; 1874.



THURSTON ON BRONZES.
FAC-SIMILE AUTOGRAPHIC STRAIN DIAGRAM.

PLATE I
TRANS. AM. SOC. CIV. ENGR'S
VOL. X No. CCXIV.

the copper-tin-zinc alloys, is one that has been well studied and is of remarkable value. This metal was discovered by Mr. J. A. Tobin (U. S. Naval Engineer Corps), and described to the writer several years ago. § It consists of copper, 58.22; tin, 2.30; zinc, 39.48; it is hardly as strong as the alloy already described, but as cast had a tenacity of 66 500 pounds per square inch of original section, and 71 378 per square inch of fractured area (4 575 and 5 019 kilograms per sq. cm.) at one end of the bar which was, as usual, cast on end, and 2 per cent. more at the other. This alloy, like the maximum metal, was capable of being forged or rolled at a low red heat or worked cold. Rolled hot its tenacity rose to 79 000 pounds (5 553 kgs. pr. sq. cm.), and when moderately and carefully cold-rolled, to 104 000 pounds (7 311 kgs.). It could be bent double either hot or cold, and was found to make excellent bolts and nuts.

A large proportion of the alloys on the copper side of the crest marking the line $z + 4t = 50$ may be treated with equal or greater success, and there should be no trouble in securing copper-tin-zinc alloys of tenacities between 75 000 and 100 000 pounds per square inch (5 273 to 7 030 kilogs. per sq. cm.), by intelligent and skillful working. As I have elsewhere stated, ‖ the metals used should be perfectly pure (Lake Superior copper; Banca or Australia tin; and New Jersey zinc); they should be protected from oxidation when fusing, carefully fluxed with phosphorus or other good deoxidizer, poured quickly into chills, cooled with the utmost rapidity, and the castings, when possible and safe so to work, rolled or forged either cold or hot. Should the work of the U. S. Board to Test Metals ever be resumed, this is likely to prove one of the most important and profitable lines of investigation. The results here given, it is obvious, are subject to revision after more work has been done, and the revision of data already obtained, the exclusion of unreliable and valuable observations, and the formulation of more precise deductions will furnish employment for future investigators.

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§ By letter dated Feb. 6th, 1876, and verbally in 1875.

‖ Metallurgical Review, 1877; Mechanical Treatment of Metals.

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CCXV.

(Vol. X.—January, 1881.)

RENEWAL OF THE FOUNDATION, AND TRANSFER OF A LIGHT-HOUSE IN PASCAGOULA HARBOR.

By J. W. PUTNAM, Associate A. S. C. E.

READ DECEMBER 1, 1880.

The coast of the Gulf States is a low, sandy foundation, presenting no bold, abrupt headlands, and very few points where a depth of water sufficient for small schooners can be found near the coast line. The bottom is a long, gradual slope extending for several miles seaward. The outlying islands are loose banks of sand continually changing in contour by the force of storms from different points of the compass.

The Government finds it necessary to maintain lights on the islands

near the channels, and to mark the channels by buoys. A great difficulty in maintaining light-houses arises from the shifting character of the islands. It is difficult to excavate to any great depth, as the water washes in, bringing with it the loose sand.

Screw pile foundations were adopted some years since by the Light-House Department, but the piles cannot be driven to a depth below where they are liable to be washed out in a single storm. Some islands have been cut in two, and channels formed through, while others have entirely disappeared.

The channel entrance to Pascagoula harbor and river (Plate II.), is between the east end of Horn Island and the west end of Petit Bois Island. The light is on Horn Island, and was built a few years ago near the centre of the island, north and south, on screw piles. Gradually the island has been disappearing, and the sea approaching, while the point of Petit Bois, across the channel, has been extending. Brush mattresses were placed along the front, and secured by piles to protect the light-house, but were about as effective as the commands of King Canute. To resist the strength of the waves, they were about like spider webs in the path of a locomotive.

The erosion progressed until the sea stood there four, five, six feet deep, under one side of the light-house, excavating and filling according to the direction of the wind, but always carrying out more than was brought back. A removal of the light-house was found to be its only salvation, but its removal a mile to the westward would necessitate a change in the charts.

Not desiring to make such extended and expensive changes, Capt. W. H. Heuer, (Corps of Engineers, Member A. S. C. E.) light-house engineer, in charge of the district, turned his attention towards creosoted piles, with which a foundation could be made, reaching to a depth below the deepest water of the harbor or pass, and through which the storms could drive without injury.

Borings made on the island revealed the fact (Plate II.), that it was a bank of loose sand, and worn and broken shells, to a depth of about twenty feet. Below that was an old and submerged grass marsh, from which pieces of sod were brought up, containing all the little roots and fibers of the ordinary marsh sod. It had evidently been formed at or above the surface of the water, and plainly indicates the subsidence of the continent.

Below this marshy, vegetable deposit of about twenty feet, was found a hard, sandy stratum, making a firm and solid bearing for the piles. Yellow pine piles, seventy-five feet long, were procured and thoroughly creosoted at the creosote works of the New Orleans and Mobile Railroad.

As the piles were to be driven as near the old site as practicable, and in barely water enough to float a pile-driver—no pile-driver could be had with leaders (or gins) tall enough to swing its hammer over the top of a seventy-five feet pile. One was procured from the railroad company having leaders over sixty feet high, and carrying a five thousand pound hammer; the leaders being adjusted by machinery, so as to drive a pile at any desired angle. With a powerful force pump the piles were washed down until the hammer would pass over the top, and from there they were driven to a depth of fifty feet below the water line.

The nature of the work, and fluctuations of the tide, rendered progress slow and tedious, less than one pile a day being driven.

Three piles were driven at each corner of the house, and one in the centre to support the lamp. One pile at each corner was driven vertically, and the other two obliquely, spreading from each face of the house at an angle from the vertical of about one in four. The three were then faced and brought together and secured by heavy bolts, making a firm and steady foundation. At the top of the vertical pile is framed a tenon six inches in diameter by eighteen inches long, which enters the iron socket formerly occupied by the iron pile, and the flattened ends of the oblique piles press against the sides of the iron socket (see Plate III.).

The light-house was transferred from the old to the new foundation over a trestle twenty feet high, and with such care that its delicate revolving machinery performed its accustomed work at night, never failing to flash a welcome to the mariner. The keeper, Capt. Freeman, says that it never stood as steady as at present.

It is, I think, the only light-house foundation of its kind in existence. It offers a solution to the question : What can be done to render secure and permanent the sand-bar lights ? It is comparatively cheap, and if as indestructible by decay and the teredo navalis, as all appearances indicate, will outlast iron piles.

When the New Orleans and Mobile Railroad built their creosoted bridges, a few piles were driven alongside to be removed for examination from time to time. The Superintendent having decided a few weeks ago

SECTION OF HORN ISLAND AT THE LIGHT-HOUSE

showing the old iron screw foundation and the new creosoted piles foundation of the Light house

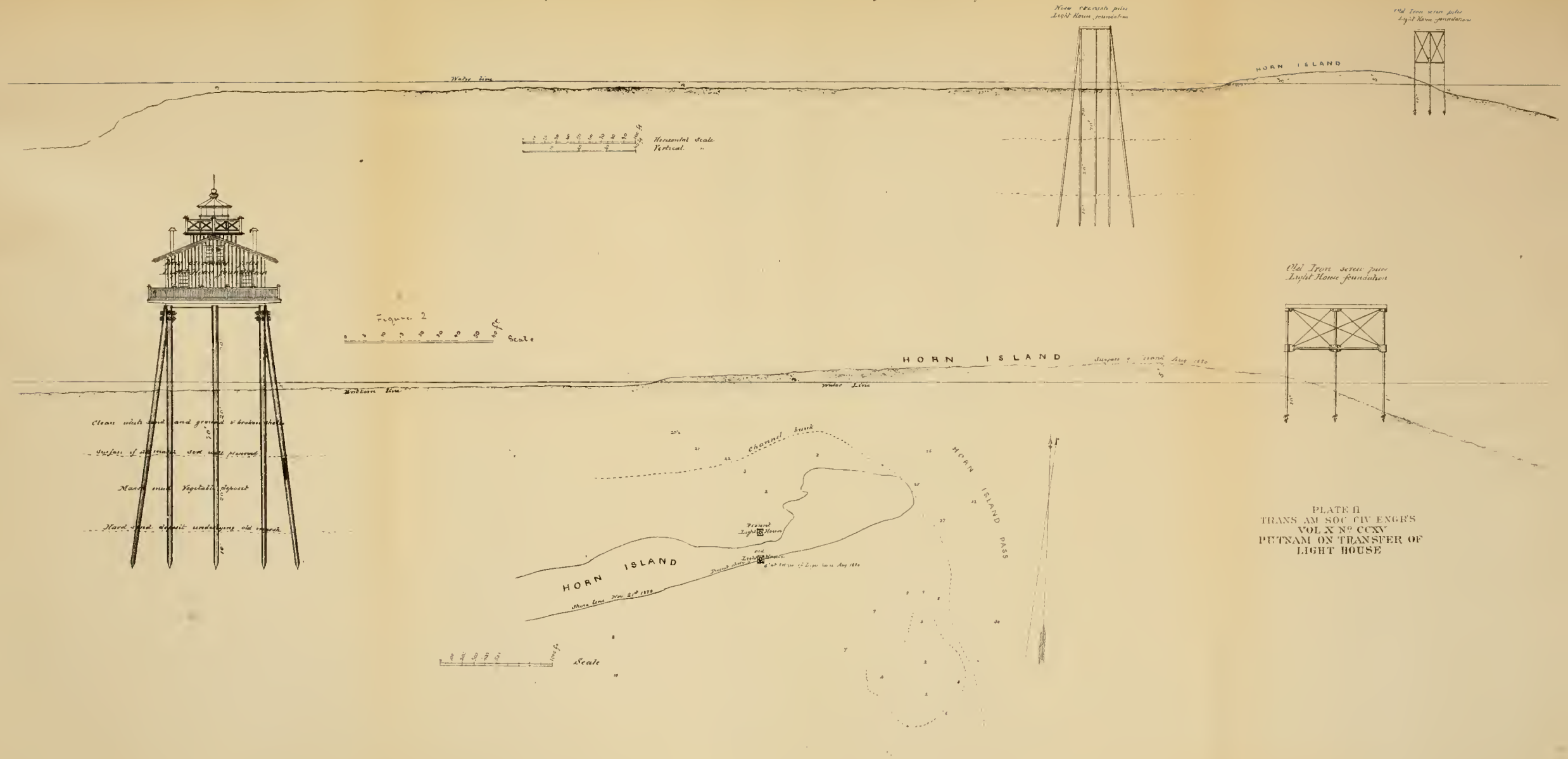

PLATE II
TRANS AM SOC CIV ENGR'S
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PUTNAM ON TRANSFER OF
LIGHT HOUSE

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to make one of these examinations, invited several gentlemen, among them some officers of the United States Engineers, to be present.

Two piles were taken out, one of which was driven in the autumn (December, I think) of 1872, and the other in June, 1876. They were beside different bridges, but where piles have been frequently cut off by the ship-worm in one year. Both piles were perfectly free from any marks of the teredo.

I have to-day made examinations of one of our oldest creosoted bridges, and find both piles and superstructure in the most perfect condition, though, had the timber not been creosoted, some of it would have been so far decayed as to require renewal.

During the discussion of this paper, questions were asked by several members of the Society, and have been answered by the author as follows :

What did the work cost ?

J. W. Putnam.—Three thousand dollars; this included the cost of the 13 creosoted piles, 75 feet long, towing the pile driver to Horn Island and back, driving the piles, building camp, building a trestle over which to move the house, the timber and lumber required for blocking and stagings, and all labor from first to last ; the trestle was thirty feet wide, and strong, and braced to stand any probable storm ; the house weighs about fifty tons, I think, from the indications while handling it. The bents of trestle were fifteen feet, from centre to centre, resting on a floor of short plank, five feet wide underneath the sills; the stringers were thirteen inches by sixteen inches, and the timbers placed underneath the sills of the house, of the same size, thirty-five feet long; rollers were placed between the timbers and stringers; the stringers bent so that the rollers near the bents carried the greater part of the load; we found it necessary to use fifteen rollers on each side; to move the house required a heavy pair of double blocks and a pair of smaller blocks for a luff on each side, and a double six inch line to a winch on the pile driver.

Why not lower the pile the whole distance by the water process ?

J. W. Putnam.—About twenty feet of the upper part of the island is loose, white sand, and ground and broken shells ; it washes very easily, having no bond but gravity to hold it in place; before the pile could be lowered, so as to swing under the hammer, the sides of the excavation

would cave in around the pile and stop its descent, the water from the pump being diffused through the loose sand; the pile then had to be raised and lowered again, with, perhaps, the same result; in this way it often required fifteen or twenty trials to get the pile under the hammer; we used the pump to loosen the sand, while driving, at first, but found it of little value.

What were the details of the method of getting the piles down by the water process ?

J. W. Putnam.—After the pile had been raised by the pile driver, a two inch gas pipe, forty feet long, was placed beside it, the lower end passing through a staple driven near the point of the pile; the upper end was lashed to the pile; a hose leading from the pump was connected to the pipe by a union; the pump was then set in motion, and the pile lowered as the sand was washed away.

What is the level of the top of piles above water ?

J. W. Putnam.—Twenty feet.

What is the present depth of water ?

J. W. Putnam.—From one and one-half to two feet.

What distance was the light-house moved ?

J. W. Putnam.—About three hundred feet; I do not recollect the exact distance.

What will be the probable security of this light-house, standing on five supports only, in case the sand shall be washed to a considerable depth, as the paper of Mr. Putnam seems to indicate as possible or probable.

J. W. Putnam.—Though the light-house is supported at only five points, the three piles at each corner so diverge as actually to constitute thirteen points of support at the bottom; the house is about thirty feet square, and the spread of the piles gives it a base of sixty-five or seventy feet square. They are so bolted together at the top as to resist a storm that would destroy the house. I have driven them for bridge foundations in water forty and fifty feet deep, the end piles of each pier being driven obliquely, in a similar manner, and with the current running faster than the Mississippi river ever runs at New Orleans, and estimated at ten miles per hour. There was no perceptible variation in the alignment of the track. This result cannot possibly be obtained if the piles are driven vertically, and sprung for bracing in the usual way. I therefore think that if the whole island should wash away, to a depth of thirty or

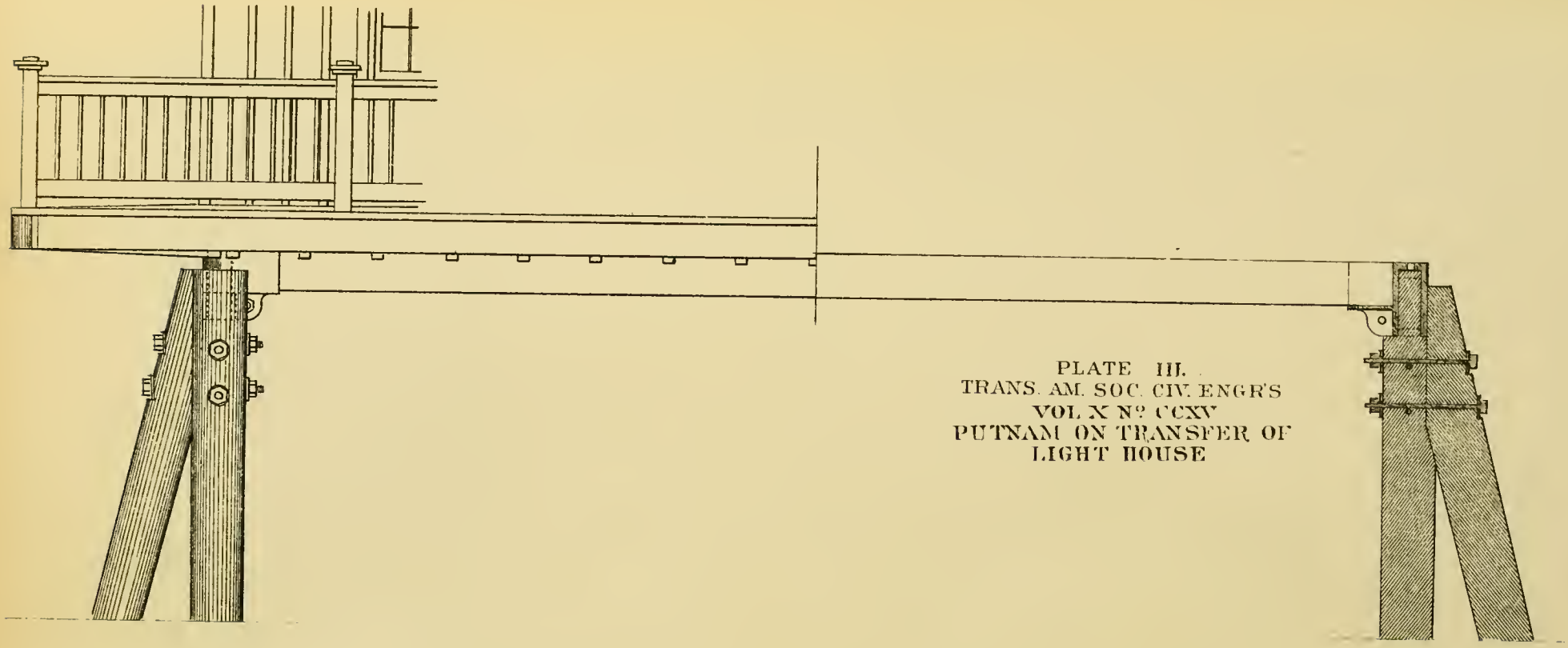

PLATE III.
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PUTNAM ON TRANSFER OF
LIGHT HOUSE

forty feet, the light-house would be perfectly safe, *i. e.*, as far as its foundation is concerned. I think it altogether probable that within the next few years the whole eastern end of Horn Island will disappear, and that the whole outlying chain of islands, that divides the Gulf from Mississippi Sound will follow suit. Perhaps the sand may drift around and pile up in dams, so as to keep a picket line for the continent. Of this I feel assured, that the old coast line was far outside the line now occupied by those islands, perhaps along the border of the great plateau, extending to six or seven hundred feet in depth of water ; that we are gradually subsiding, and that the sea is backing up the Mississippi river.

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(Vol. X.—January, 1881.)

DISCUSSION ON PAPER CCX.

WEB STRAINS IN SIMPLE TRUSSES WITH PARALLEL OR INCLINED BOOMS.

By SQUIRE WHIPPLE, Honorary Member of the Society.

PRESENTED FEBRUARY 2, 1881.

Mr. E. Sweet, Jr., Member A. S. C. E., in a paper on "Web Strains in Simple Trusses" (Trans. A. S. C. E., Nov., 1880), takes occasion to criticise the method of calculating such strains upon the assumption that the maximum stress upon any diagonal is equal to that produced by a concentrated panel-load upon each floor beam from one end of the bridge, up to, but not beyond, the panel containing the diagonal in question. This method is objected to by Mr. Sweet as faulty, inasmuch as, in practice, the panel-loads are not so concentrated upon the beams, but may be, and usually are, distributed over the spaces between beams, so

that the maximum weight does not act upon the beam until the load has progressed partly or wholly across the panel containing the diagonal, and bears in part upon the succeeding beam, thereby counteracting in some degree the stress upon the diagonal, which the assumed concentrated loads upon the preceding beams would produce.

Now, believing myself to have been the first to practice and promulgate the method of calculation thus criticised, if it be seriously faulty, I owe an apology to those, if any, who have been led astray thereby, as well as thanks for being set right in the matter. Wishing, therefore, to do what is just, and to put myself right, if I have been in the wrong, I am induced to offer a few remarks.

In all applications of mathematical calculation to practical affairs, we are usually obliged to assume as facts, conditions which are only approximately so; and in matters involving consequences as serious as those liable to result from the failure of a bridge, it is, of course, proper to assume conditions covering extreme contingencies. Now, although the maximum load of a bridge beam *usually* depends upon weight distributed more or less upon adjacent panel-lengths on either side of the beam, this is not a matter of absolute necessity. It is an easily supposable case, that a load may rest upon vehicles with wheels located at distances asunder, corresponding with the distances from beam to beam in the bridge, and each pair of wheels carrying a maximum panel-load for the bridge, in which case the beam would bear its maximum load, and the tension diagonal running upward and forward from the last loaded beam, its greatest stress, when a pair of wheels were directly over such beam, and no load upon the next beam in advance.

Such are the extreme possible conditions which the adopted method of calculation was intended to cover.

On the other hand, a load might be conceived to advance upon a bridge (though I can hardly imagine how) in such manner that each linear foot and inch should bear a uniform weight up to the front line of the advancing load, in which case, each beam would only sustain its maximum load when each adjacent panel-length was loaded throughout.

Now, neither of these supposed conditions as to the load upon a bridge, as I believe, can be shown ever to have actually occurred in practice. Neither is it easy to determine which is the more nearly, or the more frequently approximated to; every actual case possessing more or less of the distinctive features of both.

Mr. Sweet seems to have adopted the latter "assumption," while the writer, and it is believed most other practitioners have made use of the former, with satisfactory results.

The results, however, obtained by the two methods differ not largely, and, while the old method covers the extreme contingency, the proposed substitute, giving usually smaller, but never larger strains, does not as certainly cover *extreme* cases, or such as may actually occur.

I have not followed out all the details of Mr. Sweet's elaborate formulations, but consider it presumable that he has deduced legitimate results from his premises. It was hardly to be expected, however, that after entering his protest against a method of calculation based, as he alleges, upon an illegitimate "assumption" of facts and conditions, he would proceed to elaborate a method as a substitute resting upon an *assumption* which can scarcely be claimed to be more consistent with the actual conditions occurring in practice.

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CCXVI.

(Vol X.—February, 1881.)

THE SEWERAGE OF MEMPHIS.

By FREDERICK S. ODELL, C. E.

READ AT THE ANNUAL MEETING, NOVEMBER 3, 1880.

WITH DISCUSSIONS

By EDWARD S. PHILBRICK, J. J. R. CROES, GEORGE W. DRESSER, ROBERT CARTWRIGHT, SAMUEL L. SMEDLEY, WILLIAM E. WORTHEN, ASHBEL WELCH, JOHN BOGART and GEORGE E. WARING, Jr.

After nearly half a century of indifference to that virtue which ranks next to Godliness, and almost utter disregard of the simplest sanitary laws, it became apparent, after the deplorable epidemics of 1878 and '9, that some radical reformation must be accomplished in the sanitary con-

dition of Memphis; acting on this conviction, and the recommendation of the National Board of Health, her representative men determined upon the accomplishment of a sanitary revolution for their town.

At that time little had been done, practically, in the way of sewerage, and that little was done by private enterprise; there were no public sewers, and the refuse and filth were delivered into cesspools and private vaults, while not a small portion found its way into the gutters of the public streets, and these during a prolonged dry season became reeking and putrescent, and emitted the foulest odors. Nor was this all. Some years ago, many of the streets were paved with Nicholson pavement, and these had very much decayed, and readily absorbed much of the liquid filth that flowed over the rotten gutters, and in course of time became so permeated with it that the periodical flushings of rain storms utterly failed to cleanse them, and they were the constant source of poisonous exhalations. This, added to the emanations of privy vaults in the rear of dwellings, and sometimes in the very dwellings themselves, in the cellars, and within contaminating distances of wells and cisterns, created an atmosphere that was doubtless among the prolific causes of the spread of contagion.

The facts here cited were sufficiently apparent to make the better disposal of sewerage a matter of imperative necessity, but the outlook for it was not a cheerful one, for at the outset, the municipal commission was confronted by plans and estimates of cost ranging from one million five hundred thousand to three million dollars and upward. This amount, in the condition of Memphis, bankrupt by reason of official mismanagement and plunder, with the additional disadvantage of two successive seasons of distressing epidemic, resulting in the paralization of her industries and the discouragement of her tradesmen, made the possibility of raising this large amount very problematical, if not totally impossible.

During the discussions that ensued pending the approval and adoption of some practical plan for the sewerage of Memphis, the commission sought the council of Mr. Geo. E. Waring, Jr., Sanitary Engineer of Newport, R. I., who boldly advocated the adoption of a system of sewerage hitherto untried on an extensive scale in this country.

This system possesses the distinctive feature of employing the

sewers for the single purpose of conveying sewerage, and rigidly excluding all surface and subsoil drainage; the amount of water necessary to furnish conveyance for such solid matter as enters the sewers, being introduced from another source.

The "Separate System," as this is styled, although not claimed as original, has been adopted by Col. Waring, who is perhaps its most zealous advocate in this country.

The principle, "that two outfalls, independent of each other should be provided; one for the discharge of natural or land and surface waters, and the other for the discharge of artificial or house and soil drainage," and that "a system of impermeable drains should be provided, distinct and separate from the permeable land drains and sewers," "to carry off the house and soil drainage," was announced in 1849, by Mr. Philips, the engineer to the "Metropolitan Commissioners of Sewers," (London).

Although the recommendations based on this principle were not adopted for London, the principle itself contained sufficient merit to commend it to many eminent engineers who have from time to time reasserted the advantages of this system; and the contest then inaugurated has continued to the present day.

Among the many able champions of the "Separate System," might be mentioned John Bourne, C. E., who in a forcible article in 1866, advocated the adoption of two systems of drains, the large to be restricted to rainfall, and the small to house sewerage.*

But the advocates of this system have done more than merely assert its fundamental principles; they have given demonstration of the practicability of their ideas in the construction of sewerage systems in several towns in England. Among others, may be mentioned those of Reading and Oxford, also Halstead; the system in this case being somewhat modified by Mr. Edward Monson, Asso. Inst., C. E. "The sewers being coterminous with the water supply, sluice-valves being placed at the ends of the water mains, and the whole of the system being flushed by the discharge of water for cleansing the mains." The rain fall from the roofs and yards only was allowed to enter the sewers.

So recently as 1876, Mr. Waring desired not to be understood as

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*Engineering, Vol, 2, p. 267,

indorsing all that its advocates claim for what they call the Separate System, and stated "that to keep *all* rainfall out of the sewers, is objectionable for more reasons than one, for no artificial flushing which can be depended on in practice can be so efficient in cleansing the sewers, as the frequent introduction of a sufficient amount of rain water."*

The difficulty here mentioned has been overcome by the application of the automatic flush tank, designed by Mr. Rogers Field, C. E., to the head of each branch sewer, and filling these from the city water supply.

In 1879 Mr. Waring wrote: "This simple device has proved itself, both here and in England, to be entirely reliable and effective. It may safely be assumed that it has secured a reduction of the cost of drainage of small towns to one-half of what was formerly necessary."†

For the application of this system to Memphis, Mr. Waring recommended the construction of small sewers, without man-holes or receiving basins, and the placing of a flush tank of 112 gallons capacity at the head of every branch, the limitation of the size of house drains to four inches, and the exclusion of all rain water.

The estimated cost of this system was only about one-tenth of that of a complete storm water system as ordinarily constructed.

This fact, perhaps, carried greater persuasive force than either the logic or eloquence of Mr. Waring, and after prolonged discussion that developed much bitter opposition, a favorable endorsement of this system was secured, and its adoption urged by the commission. A petition for authority to raise $228,500 was granted by the State Legislature to cover not only the cost of a sewerage system, but also other sanitary work; the laying of about forty miles of subsoil drainage, and also the reclamation of the bayou, by shutting out the high water of the Mississippi by means of a dam with proper valves, and a steam pump, to pump out the bayou during high water. Even after the recommendation of the citizens commission, and its acceptance by the Legislative Council, so great was the force of general prejudice against its adoption, that much time was lost, and construction delayed until the 21st of January, 1880, when work was actually begun.

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* The Sanitary Drainage of Houses and Towns, by George E. Waring, Jr., 1878, pp. 149, 150.

† Atlantic Monthly, July, 1879, p. 61,

The work was done under the immediate direction of Mr. E. C. Metcalf, engineer in charge, Mr. Geo. E. Waring, Jr., being consulting engineer. The writer arrived at Memphis February 20, 1880, and after a few weeks spent in locating, assumed charge of construction of a section as assistant engineer.

The main sewers were located along the bayou, and ran in a general direction parallel therewith. For about four thousand feet from the outlet, one main sewer was built of brick, of twenty inches diameter, to the junction of the two main pipe sewers that ran on opposite sides of the bayou, that on the westerly side being fifteen, and the one on the easterly side twelve inches in diameter; these decreased in size to ten and then to eight inches at the upper end.

The lateral sewers were of six-inch pipe, except in a few cases, where an increased size was required, by reason of their greater length, the size being regulated by allowing a carrying capacity of about two hundred and eighty gallons per day for each city lot of twenty-five feet front, the sewers to run from two-thirds to three-quarters full.

In connection with the sewerage, the subsoil drainage received its share of attention. This was rendered necessary at Memphis by reason of its clayey formation, which prevented the infiltration of water falling upon its surface, so that subsoil water was often found in the most improbable places a few feet below the surface, and was a source of constant annoyance and inconvenience in the prosecution of the work. To provide for this subsoil drainage, ordinary agricultural drain tile, with open joints, were laid in the trenches with the sewers, and it not infrequently happened that it became necessary to lay these tile in advance of the sewers, and on a lower grade, as will be more fully explained hereafter.

The main sewers running along the bayou were located in such a manner as would best conform to the natural topography, and were carried around obstacles on curved lines whenever practicable, and thus kept at an elevation that usually avoided deep cuttings, or the building of the sewers on embankment, and as the main sewers were necessarily laid across private property, generally crossing the main streets at an angle approximating a right angle, it sometimes became necessary to carry the sewers underneath dwellings and other buildings. In low ground, when the flow line came above the natural surface, and in some other places when suitable foundations could not be otherwise secured, a viaduct was

built of small brick arches, the supporting piers being carried down to a sufficient depth to insure a stable foundation ; on this viaduct the pipes were laid, and enveloped in a ring of brick work, composed mainly of bats and broken brick obtained from a ruined building in the vicinity of the work, this was then given a coating of earth to make it secure against frost.

Great care was necessary in maintaining a true grade while laying the pipes. On account of the very small natural inclination of the bayou but very slight grades were attainable; for nearly half the length of the west side main the grade is one foot in six hundred, above that it is one foot in five hundred, and still further up one in three hundred. In order to lay the sewers carefully to this grade, stakes were set in the bottom of the trenches at stations every 12½ feet, and driven to the grade of the flow line, the pipe-layer was furnished with a straight-edge of sufficient length to reach from stake to stake, this straight-edge was just so much wider at the lower end as would represent the fall for its length, and was used by placing the narrow end in the pipe it was desired to test, and the other end on the nearest stake below the pipe, then a spirit level was placed on the straight-edge, and if not found to be level, the pipe was raised or lowered until it became so.

In some cases, as at street crossings, where the sewer came so near the surface as to endanger the crushing in of the vitrified pipe sewer at times when the ground is very soft, a few lengths of iron pipe were used.

Iron pipe will also be used for the low water outlet, and for the east side main at the bayou crossing, where the pipe is carried over on a bridge.

There are two outlets, one for high and the other for low water, and the sewerage can be turned into either at pleasure, by means of a swinging section, working in a brick chamber.

In a system of sewers like the one here described, success depends upon keeping the pipes clear and free from deposits of every kind. To do this required the greatest care during construction, consequently a departure from the ordinary methods was adopted, and the pipes were laid from their beginning toward their outlet, the joints being cemented as the work progressed ; there was thus no chance for mud and water to enter ; besides this, to avoid all occasion for deposits, great pains were taken in laying the sewers to secure concentricity and smoothness of joints. For this object an adjuster was made, which by means of three

india rubber bearings lapping the joint on the inside of the pipe, and pressing outward by turning a screw, held the two pipes firmly in position until they were secured by pressing a gasket of oakum in around the collar, the gasket serving the double purpose of holding the pipes in position and preventing the intrusion of cement, that might otherwise work through and form little ragged particles, offering obstruction to the flow, and giving lodgment to small, solid matters, in time causing serious deposits.

The flush tanks which make the separate system practicable, are placed at the head of each branch sewer of about six hundred feet in length. See Plate IV.

They are built beneath the surface of the ground, of brick masonry; the walls, four inches in thickness, in the form of a vertical cylinder drawn in at the top, and terminating with a cast-iron cover, similar to a man-hole cover, the whole resting on a concrete bottom. The syphon which discharges the tank, consists of a cast-iron discharge pipe, fitted within a larger pipe of the same material, and rising within the centre of the tank. In operation, the tank is slowly filled by a small stream of water from the supply pipe, so graduated as to fill the tank about once in twenty-four hours, or as often as may be found necessary to flush the sewers. As soon as the tank is filled, and the water begins to drip over the outlet, the syphon is brought into operation, and the whole contents of the tank instantly discharged, and the water goes rushing down through the sewer, sweeping away such small deposits as may have accumulated since the last flushing.

Many difficulties were encountered during the progress of the work and delays were twice occasioned by the failure of the parties who furnished the pipes to deliver them promptly according to their agreement.

Subsoil water was troublesome at all times, and was always found on level ground, a few feet below the surface; at the beginning of sewers it did not amount to much, but as the laying progressed the water flowed on down through the tile that was laid in the trench with the sewers, soaking the bottom of the trench and making it soft and muddy.

In such cases the subsoil drain was laid in advance of the sewers by digging a narrow trench below the grade of the sewer. Into this trench the tile were laid and covered with boards to prevent their being disturbed while laying the pipes.

At the lower end of the sewers a great deal of water was frequently

encountered and very soft bottom. Where the bottom was only moderately soft it was sometimes excavated a few inches below grade, and filled up with gravel. Where this process failed to give a firm bottom, recourse was had to piling. Saddle piles were kept constantly on hand and frequently used. They were made of boards of various length, with a semicircular piece cut out at the top of the proper size to fit the exterior of the pipe, these were driven firmly to the proper grade, the pipes laid and cemented and the trench backfilled. After the sewer was finished and the subsoil drain laid underneath the main sewer and extended to its outlet in the bayou, these wet places became speedily drained. The writer noticed especially one of the worst of these places where the pipe-layers were constantly half way up to their knees in mud and water, where the pipes were built up for a considerable distance on piles. A few weeks afterward a portion of this was unearthed for examination, as it was confidently predicted while being laid that this part would settle, and the joints become cracked. An investigation, however, showed it to be in good condition, and what was still more surprising was to find the trench quite dry and the filling firm and hard, notwithstanding there had been rains shortly before the examination. The outlet of the tile drain showed a small stream running continuously.

The sewers were laid on an average about six and one-half feet below the surface ; as but few buildings had cellars, this depth was amply sufficient.

The tile subsoil drain was laid beside the sewer in the same trench, the joints were covered with paper to prevent the loose filling from stopping the joint, they were from one and one-quarter to three inches diameter, and were provided with an outlet in the bayou.

The work was carried on until August, but comparatively little was done after the middle of June. When the writer left (June 10) about twenty miles of sewers had been laid, and so much as had been completed was in successful operation, and the practicability of the system fully demonstrated.

The advantage of this system over the ordinary system of large sewers is two fold. It is cleaner and cheaper, cleaner because the pipes are kept constantly flushed and thoroughly ventilated ; cheaper, because there is a vast difference between the cost of a large brick sewer with its manholes and receiving basins, and a small pipe sewer with its simple fresh air inlets. The difference is very apparent when it is considered that the

FIELD'S AUTOMATIC FLUSH TANK.

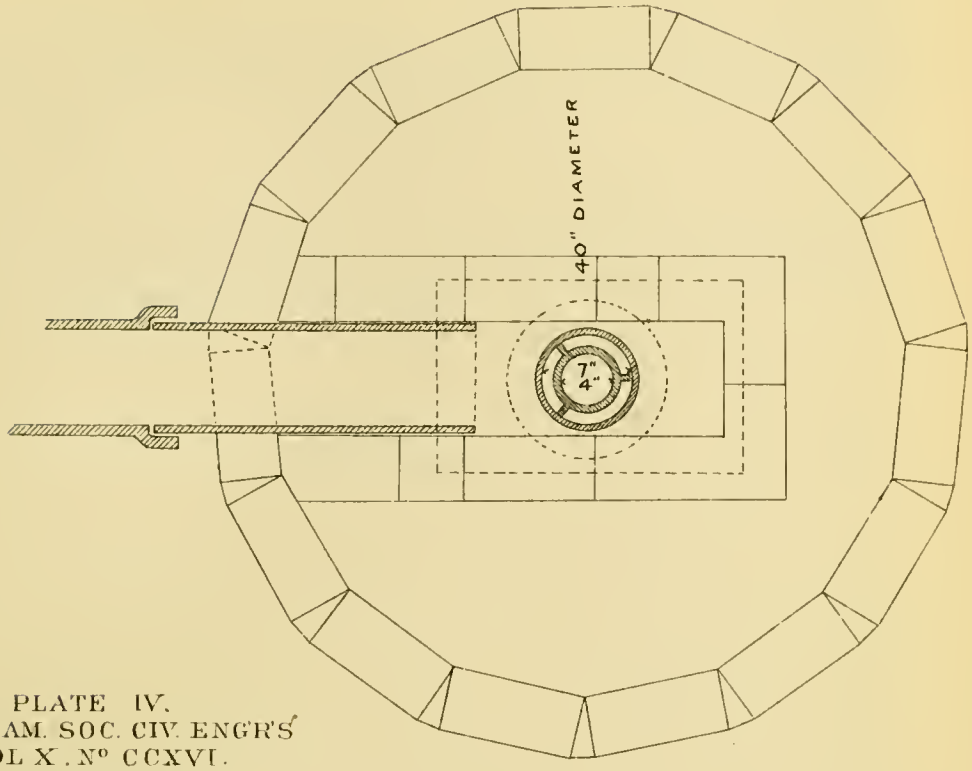
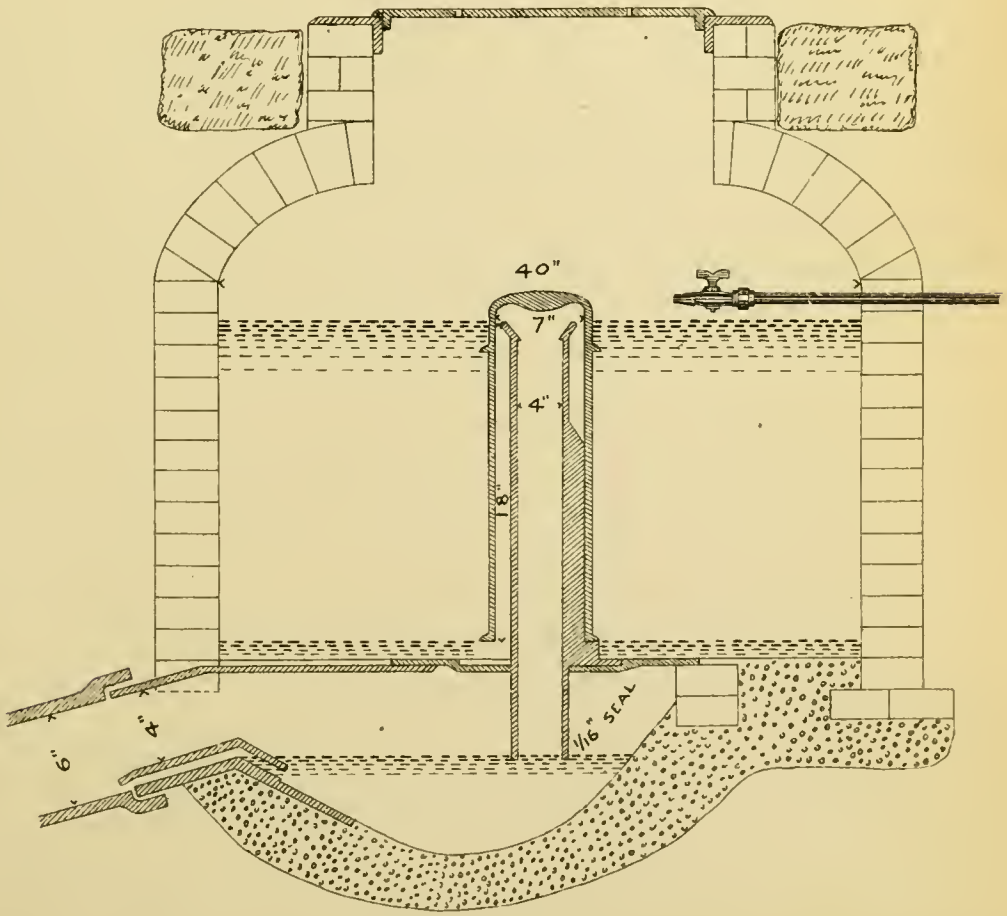


PLATE IV.
TRANS. AM. SOC. CIV. ENG'R'S
VOL X. Nº CCXVI.
ODELL ON MEMPHIS
SEWERAGE.



total cost of twenty miles of sewers in Memphis, for labor, materials, engineering, superintending and incidentals, including the two main sewers was about one hundred and thirty-seven thousand dollars ($137 000).

With the results already achieved by this small pipe system of sewerage, it seems safe to predict that a new era has been inaugurated, and that the coming years will witness great modifications in the prevailing methods of sewerage.

Discussion of the Paper.

Edward S. Philbrick.—I have listened to the paper that has been read with considerable interest, for it presents a subject that has not been discussed in our Society before. I am not prepared to criticise the introduction of the separate sewer system in Memphis, because I am not sufficiently acquainted with that city, but I would express my opinion as to the general applicability of this system. The gentlemen who have been instrumental in introducing that system in this country, especially Col. Waring, are all very sanguine of its being very generally applicable for sewering our large cities. There seem to me to be certain prescribed limits, depending on two or three points. First, the disposition of the surface rainfall. However proper it may have been to ignore the surface water in Memphis, there are certain of our modern cities where it cannot be ignored, and cities even smaller than New York, especially in our northern climates, as Albany and Boston, and which have paved streets impervious to water at all times. There are times when bodies of snow and ice are suddenly thawing in the spring, when without an adequate provision for taking surplus rainfall from the ground, our streets would hardly be passable ; so it seems to me we cannot ignore in our climate, provision for taking off this water by underground conduits. Now, supposing such a system must be provided, the great argument in favor of a separate one for the sewage, viz., its cheapness, would depend largely upon local circumstances which would differ. I have no doubt there would be places where the duplicate system, one for rainfall and one for sewage could be constructed more cheaply than the combined system. That is to say, in cities where the rainfall can be readily got rid of to some proper place by short lines. But on the other hand, where the lines for the conduits for the rainfall are necessarily long, these conduits would require a large section corresponding to the large volume of flow which would accumulate in such length, and the cost of the duplicate system would be greater than that of a combined one. There is another objection to the separate system which may not have existed at Memphis, which would have to be taken into account in many towns where the rainfall would have to be discharged into a smaller stream than the Mississippi. In all our large towns, particularly in the

summer, and also on the thawing of a winter's supply of ice in northern cities, the waters that run in our gutters, and which we wish to get rid of, are as filthy as our sewage. The rainfall in the streets of New York at certain times would be quite as objectionable, if turned into a small stream, as the sewage of houses. If either is led into a small stream, the result would be its contamination and a mass of *debris* in the channel, which would not be endurable ; so that a separate system of pipes for sewage alone would not relieve us. This pollution of streams has caused a great deal of trouble in England. We can hardly appreciate the trouble which has arisen there. In many districts, though you probably all have heard of it, in the last few years it has become an evil of so great a magnitude that it is considered one of the most difficult questions to be encountered, what to do with the sewage of towns.

There are, unquestionably, many towns where a separate collection of the sewage would be a great advantage. Such is the case wherever the sewage must be pumped or treated artificially, or used for irrigation of land. In these cases, the introduction of rain water becomes a great encumbrance. Its maximum volume is large, and attained only on rare occasions, therefore, not only must the conduits be large, but also all the plant for handling and treating the sewage, a part of which plant will lie idle and useless for most of the time. Moreover, if the sewage is used for irrigation, the rain water is most abundant at times when it is not needed for the growth of the crops; in fact, it becomes an injury to them, while in times of drought the sewage may be barely sufficient for their wants. So the sewage farmer gets most sewage when he needs the least and gets least when he needs the most. It is not surprising, then, that all men who have been, or are now, interested in sewage farming should be zealous advocates of a separate system of pipes for collecting the sewage by itself, without rain water.

Moreover, in many other places a separate system of sewage can be carried out with success, where population is so sparse that the streets will not be very filthy at any time, and in such towns as cannot afford to provide extensive conduits for rainfall, and where the character of the soil may be so porous as not to require the construction of such conduits. Reverting to Memphis, I am aware that the circumstances are represented to be such in that city that the amount of rainfall is got rid of readily without encumbrance, but I don't think this is a fair test, if applied to many northern cities. There are also many matters of detail

in the Memphis sewers which I would question. Among others, the absence of man-holes. Now, in constructing a separate system for sewage alone, the cost of man-holes would be a very large item, the pipes being small, and their absence in Memphis is, therefore, a very considerable item when compared with the cost of the sewers alone. It seems to be questionable whether any permanent success can be had by building a large number of sewers in such a condition. You all know we cannot prevent substances going into them that should not go there—garbage, rubbish, boots and shoes, etc. Those who are familiar with the care of sewers in our old cities, find many such things are to be taken out. In short, I think the system of sewers, without man-holes, cannot be operated smoothly for any length of time.

J. J. R. Croes.—The paper under discussion explains very clearly the fact that the flush tank is the one feature in the sewers constructed at Memphis, which renders the system adopted practicable. In the official statement of the National Board of Health on the Memphis sewerage, it is said, "this flush tank is one of the essential features of the "combination; indeed, without it, the use of any sewers not receiving "storm water would be extremely unsafe."

The successful working of this ingenious appliance depends upon two conditions; a constant supply of a small stream of water, and the keeping of the two syphons in clean condition. It seems to me to be possible, that in the difficulty of maintaining these conditions may lie a serious obstacle to the permanent success of the system which is entirely dependent upon them. There is so much sediment in the water supplied to most of the towns in the West and South, and this sediment is deposited so quickly in still water, that it does not seem unlikely that frequent obstructions might occur in the tanks into which the water flows at the rate of only a gallon in twelve minutes, to be emptied only once in twenty-four hours. The stoppage of the lower syphon, in the exit pipe destroys the action of the upper annular syphon, and the water dribbles through instead of rushing out in great volume. The obstruction of a portion of the annular opening of the main syphon has practically the same effect, or if it does work, it empties the tank so slowly as not to produce the desired effect. It is an open question, which the short experience had at Memphis has not yet decided, whether a delicate mechanical contrivance like this can be depended upon to work automatically for a long time, and whether the cost of inspection and maintenance

of a great number of them will be less than the interest on a larger investment which costs less to maintain. Besides, any failure or deficiency in the water supply such as is likely to occur in all of our towns in seasons of drought would be apt to affect the system injuriously.

The Memphis sewers were constructed, as is evident from Mr. Odell's paper, with great care, under the immediate supervision of intelligent engineers. The system was on trial, and the work was executed with the exactness of a sample work. Its successful working during the six months of its existence has made it a good advertisement of the system, not intending the word advertisement in any offensive sense. As a result of this, it is understood that a company has been formed to apply the same system to any town at moderate rates. I cannot think that this mode of sewering towns by contract for a gross sum, untrammeled by interference with details on the part of the engineers acting for the other party to the contract, is conducive to good workmanship or satisfactory results. "Lump contracts" are seldom properly executed throughout, and the tendency to slight or omit some important feature is too great to render such a procedure generally advisable.

Some of the details of the Memphis work, as reported, must be considered as of doubtful value. Mr. Philbrick has alluded to the absence of any provision for examining the pipes and removing possible obstructions without digging up the street and breaking the sewer. Whether the saving of first cost in this manner will prove an economy is yet to be demonstrated, and experience alone will show. It is one of these questions which cannot be reasoned out, and the experience of Memphis will be of great value in its solution.

The method of adjusting the pipes so as to secure concentricity is of doubtful value. A channel which is smooth on the bottom is better adapted to the flow of sewage than one in which the irregularity at the joints is distributed around the circumference.

The gaugings of sewers made by Mr. Waring by order of the National Board of Health, and published in the supplement to their "Bulletin" for September, 1880, show as nearly as can be judged, that the ordinary maximum flow of sewage alone, from a population of 1 000, in moderate sized towns, with plentiful water supply, would occupy an area of about from 10 to 12 square inches, or less than one-half of a six-inch pipe. The main flow being below the centre of the circle, it is much more import-

ant that the bottom should be true to line at the joints, than that the axis of the cylinders should be a straight line.

The emptying of the flush tanks can fill the pipe for only a short distance from the tank, and, consequently, the useful effect of the flushing is actually diminished by the device employed to ensure straightness of axis.

The supporting of the pipes in soft places on the ends of boards does not appear to me a good plan for durability, though it unquestionably facilitates construction very much. The plan adopted of laying the pipes down hill was a good one, but is not entitled to the claim of novelty which has been made for it. It was adopted in some of the sewers laid in the Twenty-third Ward of New York by the Park Department, three years ago. In the specifications of the contract for building a sewer in Third avenue, One Hundred and Thirty-fourth and One Hundred and Thirty-fifth streets, prepared by Mr. E. B. Van Winkle, Member A. S. C. E., which contract was let on August 21, 1878, it was provided, that "all pipe sewers shall be commenced at their highest points, and laid down towards their lowest points, unless specially advised to the contrary." It is very probable that it has been done elsewhere also.

The gaugings of sewers made by Mr. Waring, to which I have alluded, are of great interest, and ought to be republished in more complete and accessible form. If the National Board of Health would now direct gaugings to be made of the maximum flow in storms from sewers, much important information might be obtained as to the proper size for "combined" sewers. Storm-water conduits have to be built in most towns, and the determination of their minimum allowable size appears to me as important from an economical and sanitary point of view, as that of the size of "separate" sewers.

George W. Dresser:—This system involves the construction of one set of sewers to take the house drainage, another for the subsoil drainage, and still another for surface water. Now one good system, I think, is better than three, and from what I have had to do with sewers, I would rather have one good one than three. The sewers built in the town of Lennox, Mass., several years ago, give satisfaction to every one there as far as I know, but that is in a country town, sparsely built, with several acres of ground to each house, on each side of a very few streets. But that is different from putting small pipe sewers through New York. With a house on every 25 feet, we have very nearly five hundred houses

from Fifth avenue to the river on a street like Twenty-third street; and nearly all of those houses have a great pipe delivering its sewerage, surface and roof water into the sewer. There is no chance for infiltration, and the greatest rainfall must be provided for.

Another point claimed with reference to these sewers, as proposed, is their certainty of always being clean. I don't think time enough has elapsed to settle that point. A gentleman, somewhat interested in the matter of the drainage and sewerage of houses, showed me an experiment that he instituted last summer. Coming through his room was an ordinary waste pipe, a soil pipe 4 or 6 inches in diameter, made of cast iron; it came from the floor above directly through this room, carrying the waste water of the apartment above to the sewer. He made an opening into this pipe by which he could observe the effect of the use of the pipe upon the pipe itself. It was arranged with a down ventilation, and after that pipe had been up, I think two years, there was a coating of at least half an inch in thickness adhering to its interior, and this was a vertical pipe which was flushed every time it was used. That lead me to conclude that if a crockery-ware pipe of the same size, was laid horizontally, it would be more likely to clog than a vertical one. If that coating formed on a vertical pipe, why should it not form on a horizontal pipe? I should think the experiment at Memphis should have more time before its ultimate success can be determined.

With reference to the man-holes, the only alternative that is left is in case of obstruction to dig up the sewer, clear it and replace the same. Now every one knows how difficult it is to replace work that is once broken up, to dig down and get the pipe back in as perfect a condition as it was before it was taken up, is almost impossible practically. With reference to rubbish, it is very remarkable what rubbish does get into an ordinary house pipe. In a case in my own house, I found in going to the water closet one morning, in pulling the plug, that the thing didn't work; the water did not run off. I sent for a man to see what was the matter, and there he found a large sized scrubbing brush, carefully deposited in the trap. It had easily slipped from the house maid's scrubbing pail, but the trap could not pass it along. Had the trap been large enough to allow it to float through, it would have formed a serious obstruction in a 6-inch crockery pipe.

Robert Cartwright:—I find in the kitchen waste water a much more formidable agent in closing house drains than the discharge

from the water closet. My attention has been directed for some years to the closing of drains by the fatty deposit introduced with the dish water and kitchen slops, and my experience has been, that it is due to the lowering of the temperature of such waste as it enters the line of sewer, and congealing the fatty matters upon the interior of the drain. Daily additions, more or less, render it only a question of time when the largest drain will be completely stopped by it. This it seems to me will be a serious objection to the system as proposed by Col. Waring. His periodical flushing of the drains by means of flush tanks, will not remove that greasy deposit, for it sticks like a brother to the pipe, but rather tend to reduce the temperature of the drain and congeal the fat all the more rapidly.

I have been recently obliged to take up a drain in my cellar, on account of its being closed. I found at the point where my kitchen sink connects by means of a 2-inch lead pipe with U trap to the 6-inch cement sewer, that the two lengths nearest the inlet were completely filled with a compact mass of the consistency of tallow. Beyond these the drain was only partially filled to a point some fifteen feet away, beyond that all was clear. I have, about 25 feet away, a 4-inch cast iron pipe carrying into the drain the waste from a sewing machine hydraulic motor and two water closets, but there was not the least deposit there, though the closets have been in use for my family of thirteen for some six years. About two years ago I had to take up the drain at the same place, and found the same state of facts existing.

I experimented with potash, dissolved in hot water, and found that it would dissolve it, if in contact long enough, but the effect was to cut a small channel to the bottom of it, thus only partially clearing the drain, leaving but a small opening, to be closed again very soon. Besides that the expense was too great for potash, even for the small opening it made.

Obviously, it would be of no use to turn in steam or hot water, as that would only shift it to some more remote point, to the street sewer possibly, to be there congealed and cause a stoppage, where it would require greater outlay to remedy.

Inasmuch as oleomargarine was first obtained from fatty matter collected on balls of horse hair immersed at the outlets of the sewers of Paris into the Seine, I think that unless a means can be devised to dissolve, and keep it in solution, with the sewer water as a vehicle to carry it off, we shall be obliged to remove it mechanically as heretofore, and

then there is a fortune awaiting some individual who will collect this material for the market.

In my own drain my rain conductors connect with my sewer beyond the point where kitchen connection is made, as also my barn and workshop waste. This gives me the benefit from washing carriages, and a Backus motor discharge constantly running its water to flush the drain, but it stops at the kitchen connection, notwithstanding all the water turned in. This is certainly tangible evidence that cold water won't prevent stoppages caused by kitchen slops.

Samuel L. Smedley :—Notwithstanding the greatest care in flushing, grease and other adhesive substances will accummulate on the sides of the drains, and this is liable to increase, as has been here stated, until the pipes become closed with fatty matter, which, when cold, becomes stiff and hard.

In Europe, where these small pipes are used extensively, the man holes are placed very close together, so that the obstructions can be removed manually, by operating between two manholes.

Mr. Fowler, of New Haven, informs me that he introduces wooden balls, somewhat less than the size of the pipe. Several of them are joined together with cords, and the flushing under a head causes the water to spurt around the balls with great effect, thus tearing away and removing the obstruction.

Solutions of potash are sometimes used, but this is not generally satisfactory, because only a narrow opening is cut, leaving the bulk undisturbed-

Although the flushing tanks in Memphis may be generally effective, I think the pipes will frequently become choked. I do not see how these obstructions can be got at and removed conveniently with such a limited number of man-holes as Mr. Waring has put in.

I agree with what has been said here on the necessity of providing a full system of sewers for storm water in large cities. The natural drainage areas covered with houses, are so enormous in many places, that the surface accumulations from an ordinary rainfall would make the crossings of streets impassible to pedestrians. Many such areas exceed 1 000 acres. The Cohocksink basin in Philadelphia, contains 2 500 acres, and the summit is 25 000 feet from its outlet at the river, with paved streets nearly the whole distance. An eighth of an inch rainfall in one hour, would fill the lower streets a foot deep from curb to curb. The public convenience

demands that storm water should be removed from the surface of the streets, as speedily as possible, and to do this sewers of great capacity have to be built, capable of carrying from ten to twenty times the quantity of sewage proper. These large sewers are, of course, enormously expensive; but they have to be built to accommodate the public. Where is there a large community which at this day would bear the additional expense of a complete separate system for house drainage? The fact is, we need to have all the available daily flow of water introduced into these sewers, so as to aid in cleaning them when there is no rain to carry off the sediment. The separate system may be adopted very satisfactorily and economically in small towns, or in narrow cities spread along a river front, when the rain water will quickly flow away without too much accumulation; but large cities generally will require large sewers to get rid of storm water, the cost of which is burthensome enough without the expense of an additional system. Some engineers thoughtlessly say "build storm water overflows for relief," which is an absurd proposition where the main sewers do not run parallel to a river or stream, but are built, as they generally are, nearly at right angles to a river, in the direction of the natural slopes of the territory.

William E. Worthen.—In Brooklyn, where many large areas have been graded in the interest of the land owners, from considerations of economy of excavation and fills, and large pockets or basins have been made thereby, the rain water cannot be discharged by the street gutters alone, and even with the most approved system of street grades this city, from its position, its large extent, and the great length of water courses necessary for the removal of rainfall, would still, for this purpose, require deep sewers. Such sewers have been constructed there, and as Sanitary Engineer of the Metropolitan Board of Health, I have examined many and found no reasons why they should not serve both purposes—removal of rainfall and house sewage.

In cities there are three purposes to be served by sewers, or their equivalents: the drainage of the ground below the level of the cellars, the removal of rainfall and the removal of house sewage. The first is, in a measure, served by the construction of box drains along the lines of small water courses, which, in the early occupancy of a town, are often necessary to prevent the grading of the town lots from obstructing the flow and forming stagnant pools. But when the box drains are covered by deep fills, but little water gets into them. When the streets are

graded and lots filled, provision must be made for removal of the rain, and if the streets are not paved it is the simplest way to make use of gutters and open drains; but when the streets are paved and houses built, so long as the underground drainage is served by the old box drains, and the rainfall can be taken off by the street gutters, a system of pipe drains will serve very well for the removal of house sewage. But as by the regulations of Boards of Health in the neighborhood, back yards are to be connected with sewers, and as no gutters from leaders are allowed across sidewalks on account of the winter ice, at least two-thirds of the rainfall is to be taken off by sewers. If, therefore, a single system of sewers can be made to serve for the removal of ground water, rainfall and house sewage, it would seem to be the simplest and best; but the function of street gutters should not be overlooked, and provision should be made, by so grading the streets, that the rainfall thereon should, as much as possible, be taken off by the gutters—to keep the sewers of as small dimensions as possible, and provide against very heavy rains which occur at intervals of a few years. No system of sewers can be arranged without full consideration of the position of the city to be sewered, its geographical configuration, its extent, the needs and habits of its citizens, and its financial ability.

J. J. R. Croes.—The precise effect of the flushing tanks has not been accurately described in any account of the Memphis works that I have seen. A number of letters from itinerant committee men who have been taken to a hole near a tank and allowed to look in at the proper time and see a rush of water, have been published in the newspapers all over the land, but no engineer has, so far as I know, given any account of the distance from the tank that the high velocity of the flushing water is maintained. From each tank, once a day, 15 cubic feet of water are discharged in 35 to 40 seconds. The initial velocity of discharge through a six inch pipe is therefore two feet per second. This velocity is, of course, soon lost, and it would be interesting to have some observations on the fluctuations of velocity and depth of water in the pipes at points some distance from the tank connections. In operating the system it would be useful to know also how the discharge of the several tanks should be arranged as to time, so as to produce the best effect. These details are of so much value to those who will have to pass judgment on the system as applicable to different places, that it is hoped that some engineer will examine into them and report the facts.

Edward S. Philbrick.—I believe the flushing, as practiced at Memphis, serves very well for the pipes in the immediate vicinity where it is applied. The velocity of the stream—the flushing stream—is never more than that due to the fall, and this extra fall is soon distributed over a considerable length, and therefore looses its efficiency in a few rods.

The durability of stoneware drain pipe has been questioned. I have recently been taking up some old drain pipes that I had laid from a house 25 years ago—some of the first pipe made in this country—and I was gratified to find it perfectly clean, and absolutely in the same condition as the day when laid. They were 5-inch pipes. At the same time iron pipes would not remain clean, for they would be subject to some corrosion, which serve as a nucleus on which slime collects. Iron pipe should always be used inside of the building because its joints are more secure, but I think it is a fact beyond dispute that vitrified and glazed earthenware has the property of keeping clean from everything but kitchen grease. The grease that comes in with dish-water is of such a nature that I know of no means of cleaning it out except by mechanical processes. Flushing from the tanks will not remove it after it has once collected. I find that in all drain pipes having a rapid fall, grease does not collect. This accumulation of grease in pipes is a great nuisance, and wherever it has been in my power I have endeavored to intercept it by tanks, but some of it will pass through if these tanks are neglected, and the only sure way is to have a rapid fall for it.

J. J. R. Croes.—Suppose the flushing occurs only once in 24 hours, will that suffice to prevent the accumulation of grease?

Edward S. Philbrick.—I cannot say. This collection is continuous and comes in with dish-water. In this very drain, above referred to, after laying 25 years, which I had occasion to take up, I found it filled solid with grease for about six feet in length, near the house, from neglect of the tenant, who omitted to clean the grease from the tank provided to intercept it, and it would have passed very well for oleomargarine. The first thing we knew of it was the backing up and overflowing of the sewage obstructed by the accumulation of grease. There was no other way or vent but to back up and go into the rain-water cistern through its overflow, which was injudiciously connected with the drain.

Robert Cartwright.—The countries in Europe might live on what we waste through our sewers. We actually waste more than would keep

a nation alive. The separate system may work in England for a time, the same way as the Tay Bridge stood for a while, but it came to a short end.

Ashbel Welch.—From the descriptions of the topography of Memphis it appears that the distance that the storm-water had to go is in no case more than three or four blocks to an outlet, and that there are no pockets like those mentioned as existing in Brooklyn.

John Bogart.—The criticisms we have heard to-day upon the plan of sewerage which so far has been in successful operation at Memphis, have been severe, but this criticism will be advantageous in developing what good there may be in it, if any exists. I do not understand that the system described was adopted for Memphis without deliberation. In fact, I understand that it was adopted upon the recommendation of engineers who had given the matter very particular consideration, and who decided to recommend this system after a careful comparison of the plan proposed under it, with other plans for the sewerage of that city drawn up with provisions for taking the storm water. Of course the element of expense was serious, and I believe that it was deemed impossible to raise in that city enough money at that time to pay for the proposed storm-water sewerage. If this system that has been adopted does not work at all as has been prophesied, or only works for a short time, the fact that it is cheap will not make it economical; but if it does work for a few years, and even if after that time it does require additions, as for instance, man-holes, the beneficial results to the health of that city will doubtless be enormous. The fact is that a system of sewerage has been put in at Memphis which Memphis was able to pay for, and I understand that without some system of sewerage there was a probability that the city would have to be abandoned as a place of residence.

There are other cities where this or a similar system of sewerage may be applicable, for a different reason; for instance, in a large portion of the City of Baltimore it is considered by the citizens to be desirable that the storm water should run through the streets, and it is believed that the streets are kept much more clean than they would be without this storm water. The adoption of a system which would take the storm water from the surface of the streets would perhaps not be favorably looked upon, and consequently if

this system which we are now discussing proves successful, it will give such a city an economical method for disposing of its sewage.

The difficulty of disposing of storm water is much less in the southern cities than in those further north where frost is taken into account. It seems to me that, on the whole. we may look upon the experiment at Memphis as an advance step in the treatment of this important department of the provisions for life in cities, and that should it prove the decided success which is believed in and hoped for by many, we may congratulate ourselves that this has been first accomplished in the United States.

Samuel L. Smedley.—The City of Baltimore does not have the difficulty that has just been explained to us with regard to Brooklyn. Nearly all our large cities are situated just as Brooklyn is—that is, the streets are laid out in straight lines and parallelograms over territory without regard to its topography. The consequence is, there must be basins, because there is no large city that is not full of basins, because people do not follow the lines of topography in laying out their towns.

George W. Dresser.—Except Boston.

Samuel L. Smedley.—I don't think the tendency of this discussion has been to condemn the system for Memphis, under the circumstances. It was represented here, however, that there were no manholes put in the system. If that is the case, it strikes me that is a great defect.

Robert Cartwright.—The town of Stamford is now adopting that system. Stamford is nicely situated for surface drainage. They contemplate man-holes in connection with the system. The same system has been adopted for a number of years in Birmingham, England.

J. J. R. Croes.—I do not understand that the entire separation of sewage and storm water which Mr. Waring advocates, and which has been carried out at Memphis, and recommended for Newport, Stamford and other places, has been practiced anywhere in England. In what is there called the "separate system," the rain water from roofs and back yards is allowed to enter the sewer, but the street wash is excluded.

The Memphis work is attracting as much attention there as it does in this country, and the results of a continued trial of it are looked for with great interest.

The omission of man-holes does not seem to be a part of the "system." In this case it was an expedient adopted to reduce the first cost to the lowest possible point, in order to enable anything at all to be done.

George W. Dresser.—I wish to state, as a matter of information to the members of this Society, that we must not flatter ourselves that it is not proposed to put this system in everywhere. Perhaps we may admit that it will do in a small town, in all probability, however, as I have been informed, this system "is bound to be adopted in Paris, London, and many other large cities." I think it is a very happy thing that the matter has been brought up here for discussion. If we have got to take hold of it, we must make it work. We must not sit down and ignore it. The proposition is, to have separate sewers adopted everywhere, and if we have to build them, it is a good idea to talk these things over beforehand and be prepared to do the work well.

George E. Waring, Jr.—I have been much interested by Mr. Odell's paper, and by the discussion to which it has given occasion among engineers, with whose study and practice the system described is so much at variance. The subject has, naturally, been approached mainly from the side of constructive engineering. The traditions of the profession have been formulated with the prime view of getting rid of water. The prime object in the new method is to get rid of filth, or of what would become filth if not removed before decomposition, and of resultant "sewer gas."

Mr. Odell's paper is substantially correct. The commission, however, did not seek my council. I was one of its original members, and my suggestions were unanimously accepted after an exhaustive argument in favor of the plan proposed by Messrs. Hermany and Chesbrough, the former being present and taking an active part in the discussions.

In what I have to say I shall consider the paper, and the comments it has called forth, as a whole, and shall meet the criticisms advanced as completely as I may.

I have not ignored the storm-water question. I fully recognize its importance, and maintain only that it should be treated as a separate subject, chiefly as a purely physical subject, and that the manner of treating it should be such as to call for the least outlay; such as to se cure cleansing action at the surface so far as practicable; and especially

such as not to interfere with the more vitally important work of removing the wastes of human life.

The sanitary consideration should be, *facile princeps*, the controlling consideration. To this opinion the civilized world is, I think, fast coming.

There are special cases where the conformation of the surface, as in Brooklyn and in St. Louis, but by no means generally even in large cities, calls for special means for the underground removal of storm-water. There are many other cases where, from mere accumulation, the flow becomes too great to be allowed to remain above ground. But however frequent, these cases are far from being universal. Where they exist very shallow sewers would be as effective as deep ones, and no sewers are needed (for the removal of storm-water), save to relieve the basins or to remove too great accumulated flow. In favor of keeping rain-water on the surface as long as possible, there are many arguments, not the least being that we thereby retard its discharge and may restrict the mains to sizes which would be quite inadequate if the whole rain fall were delivered by conduits of great velocity.

To say that "this system requires the construction of one set of sewers to take the house drainage, another for the subsoil drainage, and still another for surface water" is not strictly accurate. It requires one complete set of sewers for house drainage, draining tiles in the springy parts of the soil (laid in the sewer trenches), and occasional sub-surface channels for the removal of accumulations of storm-water.

To say that "one good system is better than three" is specious, inasmuch as the most important function of a sewer—the complete and quick removal of matters which may become injurious if retained—is hindered by charging it with the removal of storm-water. No sewer can be entirely "good" for both offices.

Neither is the filth of the streets an argument in favor of storm water sewers; it is rather an argument in favor of proper street cleaning—such as that of Paris and of Washington. Whatever is done with street dirt it surely should not go into sewers. In making this statement I am, of course actuated, above all, by the sanitary consideration—but not heedless of other bearings of the question. These other bearings were unfortunately, an embarrassment in Memphis, for—contrary to the accepted notion—there are few towns where storm water does so much harm as it does there. I simply did not allow storm water to interfere

with the proper removal of household and other waste, but recommended suitable surface or shallow channels.

It is suggested that the gauging of sewer flow be extended to cover the flow of storm water. This would hardly be useful, for the reason that the conditions controlling such flow are not constant; too much variation results from an extension of the receiving branches, from the greatly changing volume of rain fall, and from the changing character of surface, as building and paving increase. We know more now on this subject, from actual experience in London and other large towns than any gauging could teach us.

The chief criticisms of the Memphis system which have been brought out in this discussion, are as follows:

1. Man-holes should not have been omitted.

2. The concentric laying of pipes is a mistake.

3. The board piles used for supporting the pipes in soft ground will not be durable.

4. The sewers will become foul from the adhesion of grease and other matters.

5. The flush tanks, "delicate mechanical contrivances," depend on a constant water supply; they will fail from an obstruction of the siphons; they will become choked with sediment; and as the initial velocity of their discharge is only 2 feet per second, their effect will be lost within a few rods of the tank. Also, the tanks must be nicely timed to supplement each other's action.

6. The falling of the Tay bridge indicates that though working well for a time, this system will come to a "short end."

Permit me to consider these objections in their order:

1st. The Memphis system is an entirely new system. None of the so called "separate" sewers in England resembles it except in the exclusion of street water. They admit roof water and yard water. They have no provision for periodical automatic flushing; none for the restriction of the size of the house connection, to prevent the passage of bulky objects; none for complete and systematic ventilation; and none for the exclusion of joint mortar which is a frequent source of obstruction. Then again, the pipes used in the English examples referred to are generally much larger than those used in Memphis. Therefore, the supposed need for man-holes is not necessarily applicable here. Perhaps, too, it would be instructive to know to what extent the man-

holes are used in England or here, either for inspection or for cleansing.

The sewers of Lenox, constructed in 1876 (all 6-inch) have a few man-holes. The only use ever made of these is for a very infrequent hand-flushing. There are no flush-tanks there, but roof water is admitted to the heads of the sewers from adjacent large buildings. The Lenox sewers are free and clean.

The sewers of Cumberland Mills, Maine (all 6-inch), have no manholes, and they have flush tanks. They have been in operation more than two years without stoppage or fouling. In Memphis, there are over 20 miles of sewers, and their use began in April last. In that time there have been, in all, eight stoppages ; some of these from substances carelessly left in the pipes at construction ; most of them on curves, where the joint at the outside of the sweep was open wide enough to catch sticks, bones, etc., and an undue proportion of them in the work of a single engineer who was ambitious to control the laying of too many lines at once. The whole cost of locating and removing obstructions, and restoring the sewer and the street has been about $125. for the whole eight. Incidentally we have learned how to avoid defects which have caused nearly all of them. Among other things, I have devised a handhole which will obviate the necessity for breaking the pipe, which will prevent earth from falling into the sewer during the removal of obstructstruction, and which, while adding very little to the cost of the work, will make it easy to remove any obstruction. The opening of the street will still be necessary. The cost and annoyance of doing this on rare occasions is much more than offset by the fact that we carry all house connection branches to the line of private property during the original construction, and thus obviate the much more considerable openings, which in ordinary practice are made by plumbers whenever a house is connected. In any case the occasional openings needed to remove obstructions will be trifling as compared with openings made to reach gas and water pipes —about which no engineer complains.

Some rubbish will, of course, get into the sewers and some obstructions will occur, but scrubbing brushes will generally be retained in traps and not much will pass the 4-inch house drains which will stick in the flushed 6-inch sewers. Most of the rubbish spoken of as found in sewers gets to them through street catch-basins, and in Memphis there are no such basins.

2d. The concentric laying of pipes is, in my judgment, very important. In its absence the whole irregularity of size may, and generally does, come at the flow line. It is never very great—in 6-inch pipes—and if equally divided is of little importance ; if all at the bottom, it might be objectionable. Furthermore, proper gasketing is only possible with concentric laying, and this is most necessary.

3d. The durability of the board piles is not of the slightest consequence ; when the earth has become firmly settled and compacted about the pipes, their help is no longer needed, a pipe—or a brick or a chip—once imbedded in a nidus of earth, deep in the ground, must remain unmoved, and the joints of a pipe sewer so imbedded are safe for all time.

4th. The discussion of the "grease" question seems to have answered itself. The greatest distance mentioned at which grease was found was (Mr. Philbrick) 6 feet from the sink waste. Mr. Cartwright found it for two lengths of pipe (4 feet). At a distance of 15 feet the drain was clear. If householders are careless about their grease, it is their own drains, not the sewers which will suffer. The grease found in the Seine did not adhere to the walls of the sewers. It was what had been washed out of the drains in a condition to be carried forward by the flow.

I know very well, and have often examined the soil pipe to which Col. Dresser refers. The condition of its walls is the same as is found in all vertical, round waste pipes, and is familiar to all who have investigated the drainage of houses, even casually. It is asked: "If that coating formed on a vertical pipe, why should it not form on a horizontal pipe ?" Simply because water falling through a vertical round pipe loses its flushing power by swirling. The moment a pipe is sufficiently inclined to cause a direct flow the flushing power is restored, and the pipe is kept clean. Such deposits are never found in horizontal pipes with sufficient flow. The sewers in Memphis are entirely clean, so far as the eye can detect.

5th. The flush-tanks are not a delicate mechanical contrivance any more than mill dams and stand pipes are—they have no moving parts of any sort—and they do not require a constant flow. When they receive no water they do not act, but whether their supply is regular or irregular, they discharge whenever they become full. Being lower than the houses they are sure to get their share, if there is any supply at all. There has been some trouble from the choking of the small subsidiary siphon,

and its use, and the need for it, have been obviated. The main siphon cannot become clogged by any water, no matter how impure. Its rushing discharge carries away all obstructions. The same cause prevents the accumulation of sediment anywhere in the water-way.

Perhaps the initial velocity would be only two feet per second, if the discharge of the tank filled the six-inch sewer full, and still required 35 seconds. It does not so fill it, and the velocity is very great. Instead of "losing its efficiency in a few rods," the flushing stream, according to observations make in Memphis, fills the sewer more than half full 900 feet from the tank. This distance must, of course, depend on the fall of the sewer. At 1:200 it is ample to wash all filth forward to a point where the natural flow is able to take care of it, and that is all that is asked of the flush tank. Each tank has only the dead end of its own sewer to flush. It is immaterial whether all go off at once or irregularly.

6th. The Tay Bridge comparison is not pertinent. Although the use of a system of sewerage such as is now under consideration has, as yet, had a practical trial of less than one year, it is known to the profession that indestructible pipes, securely laid in the ground, with a sufficient fall, and a sufficient volume of flow, will discharge sewage for all time. Even 12-inch pipes, not clogged with street dirt, keep themselves clean with a current not more than three inches deep, and the smaller the pipe the more cleansing the current of a given volume of sewage. No new principle is involved here, only a new application of principles which have long been familiar.

Mr. Croes says my gaugings show, "That the ordinary maximum flow of sewage alone, from a population of 1,000 in moderate sized towns, with plentiful water supply, would occupy about from 10 to 12 square inches, or less than one-half of a 6-inch pipe." That depends. Sectional area depends on velocity, and velocity depends on fall.

Mr. Croes speaks of a claim of novelty for the laying of the pipes from the head of the sewer downwards. Mr. Odell only spoke of this as a "departure from the ordinary methods," and it is that.

The same speaker cautions us against allowing sewerage work to be carried on "untrammeled by interference with details on the part of the engineers acting for the other party to the contract." This is not suggested in Mr. Odell's paper, nor, so far as I know, has it been proposed anywhere. The engineer of a city has the same control over the

construction of sewers in gross, that he would have in detail. If he can secure adherence to specifications in the building of a 6-foot sewer, he can do the same in the building of a -inch sewer. So, also, he has an influence in the selection of a plan, and in the determining of its details, in proportion to his ability to convince his municipal authorities of the wisdom of his views.

In closing, I beg to say that the adoption of the general principles of the Memphis sewerage and the regulation of its details—and, I trust, I shall not be accused of immodesty in saying it—has been no hap-hazard, ill-considered work. To the best of my ability, I have, during the past twenty-five years or more, studied with great care what has been said and done and written on the subject of town and agricultural drainage in this country and in Europe. I have considered, so far as my opportunities and my abilities have enabled me to do so, all conditions to be met, and all elements of the art. Drainage has been my specialty from the outset, and, I think, I may claim such confidence as is due to a man of common intelligence, who has made a careful, life-long study of a single branch of engineering.

I submit to the world, as the best works of which I am capable, this system of sewerage, now working in Memphis. That it is by any means perfect in its details, I do not pretend. That these details will not be greatly improved by the efforts of others, it would be fatuous to suppose. Had I had more money to spend in Memphis, some of them would have been more complete than they are.

At the same time, I am convinced that the main features of that system are strictly correct; that they afford the only relief yet devised for the defects of the prevailing methods of town sewerage—these methods being the outgrowth of traditions which ante-date the rudiments of sanitary knowledge; and that some of us will live to see the day when the Memphis system shall have supplanted the storm-water system as completely as the present development of the storm-water sewer has supplanted the huge irregular culverts of thirty years ago.

It is noteworthy that in this discussion the two fundamental benefits which my sewerage secures, have not received the faintest allusion; noteworthy because this is a meeting of engineers, more or less engaged in sanitary work, and, therefore, owing prime allegiance to the public health.

No word has here been uttered on the subject of filthy accumulations in catch-basins and in sewers too large to be cleansed by their natural flow, which the Memphis work avoids; nor on the subject of foul and dangerous gases resulting from the decomposition of this filth. No reference has been made to the fact that waste matters delivered into the head of the remotest sewer in Memphis, are shot into the Mississippi river within two hours time, and that the slight sliming of the walls of the pipes, delivers the resultant gases of its decomposition into an atmosphere so freely and so constantly renewed, that "sewer gas" is unknown there.

Deviations from the established methods of construction have been condemned, either directly or by implication; but no recognition has been accorded to features which sanitarians, here and abroad, have accepted as most essential merits.

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CCXVII.

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ON THE VENTILATION OF HALLS OF AUDIENCE.

BY ROBERT BRIGGS, MEMBER OF THE SOCIETY.

PRESENTED JANUARY 26th, 1881.

It is not too great an admission to say that the Ventilation of Halls of Audience, that is, assembly rooms, lecture rooms, churches, theatres, and similar places, has not yet been generally effected in the most satisfactory manner.

All rooms, where many people are gathered together, are liable to be-

come more or less offensive after a brief duration of session, and noticeably more objectionable as the session lengthens.

The flippant writer who records and publishes the circumstances does not hesitate to ascribe the defect to "want of scientific knowledge," with the implication that either he himself possesses, or that he can readily produce the encyclopedia which contains such information. Those who have practically to do with the erection of buildings or the construction of apparatus for ventilating and warming the same, and especially those in whose charge the finished buildings and their apparatus are placed, are well aware that the teachings of the books or the records of practice have not gone beyond the studies of requirements, most frequently under conditions not applicable to our climate of the northern United States; or further than an incomplete description of the details of apparatus, which certainly have been evolved in a very perfect way in the workshop. In this regard of apparatus as a whole, it may be averred at once, that for more than twenty years the practice of American contractors has been such as will meet every requirement of supply of air in any quantity and at any temperature desired.

The literature of ventilation is tolerably voluminous, but a few books, now over a quarter of a century old, give with much uniformity of repetition all that is written on the subject.*

Most writers are diffuse. The theory of ventilation has been based upon considerations rather than investigations. Views have to be supported in lieu of facts ascertained. The experiments and observations in

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* A Course of Experimental Philosophy, by Dr. Desaguilliers, London, 1723; Conducting Air by Forced Ventilation, by the Marquis de Chabannes, London, 1818; Principles of Warming and Ventilation, by Thomas Tredgold, London, 1824; Theory and Practice of Warming and Ventilating, by an Engineer (anon.), London, 1825; Popular Treatise of Warming and Ventilation, by Charles James Richardson, London, 1839-56; Practical Treatise on Warming of Buildings, &c., by Charles Hood, London, 1844; Illustrations of Ventilation, by Dr. David Boswell Reid, London, 1844; Dictionary of Arts, etc., by Dr. Andrew Ure, London, 1846; Practical Treatise on Ventilation, by Dr. Morrell Wyman, Boston, 1846; Traité de la Chaleur, par E. Péclet, Paris, 1843-1860; Etudés sur le Ventilation, par Genl. Arthur Morin, Paris, 1863.

The above is merely a list of the more important works. A complete list for this century is perhaps fifty volumes, mostly since 1850, with possibly important articles in a hundred periodical or serial publications. It is proper that the most valuable recent work should be named, wherein the physiology of ventilation is most clearly set forth, to wit: Military Hygiene, by Dr. Edmund Parkes, London, 1863. The last edition of this work is edited and enlarged by Dr. F. S. B. François de Chaumont, London, 1878.

The indispensable library books of reference in the above, are Wyman, Péclet, Parkes, Reid, Tredgold, Hood. * * *

the direction of chemical or pathological inquiry, have in a great measure failed to give results compatible with evident physical wants. Ventilation of occupied places, in general, means only the supply of air for health and comfort in requisite quantities. But the uncertain element in this simple proposition is, what quantities are requisite ?

The real quantity of air impaired by any one individual is small in any case, although it varies in amount with all the conditions of life and health of the individual, especially also for any one individual as to rest or activity, until limits three times in excess and one half in diminution of what is impaired in the state of comparative rest, are reached.

In air, at mean temperature of 60 to 70 per cent. of hygrometry, an adult man, when awake and at rest at his ease, in similar condition in general to one of an audience in a public hall, may be taken to make 16 respirations, of 30 cubic inches each, or 480 cubic inches, in a minute.* This inhaled air at say 70 degrees will have, when in American summer condition of humidity, about 70 per cent. of complete saturation, or about $1\frac{7}{10}$ per cent. of its volume will be aqueous vapor, and about $\frac{4}{100}$ of a per cent. of its volume will be carbonic acid, while the remainder will be nitrogen and oxygen in the usual constant ratio of about four to one which exists everywhere in the atmosphere. The exhaled air will be found to have lost about one fifth the oxygen inhaled, by the formation of carbonic acid; it will have nearly three times as much aqueous vapor, and nearly 100 times as much, or about 4 per cent. of its volume, of carbonic acid ; while, notwithstanding the greater density of this carbonic acid gas, in consequence of the increase of temperature from 70 degrees to 90 degrees, and also of the levity of the aqueous vapor, the exhaled air is really about 3 per cent. lighter than the inhaled air.

This statement of the figures of respiration has been carefully prepared, and may be implicitly relied upon. It is presented in the outset of this paper, as a foundation on which to build much of the argument to follow, and is especially intended to meet two popular fallacies.

The opinion is entertained by many people, some of whom ought to have informed themselves better, that the expired breath is heavier than the air, and, as a heavier body it falls to the ground. The contrary is certainly the case. Notwithstanding the direction given to the breath when breathing from the nostrils, the column of breath ascends in all

* Experiments of Dr. Edward Smith. Proc. Roy. Soc., 1859.

places where the temperature of the air is below 85 degrees. The diffusion of the exhaled breath, that is, its mixture into air near by, will of course take place nearer to any person when the flowing off of the stream of exhalation is impeded by the want of difference of temperature between the breath and the air. In any room at the temperature of comfort, 70 degrees to 72 degrees (with proper humidity), the diffusion of the breath will occur above the heads of the persons, and the fresh air for inhalation will be derived from the current ascending along the person ; a current induced in part by the ascensive force of the expired air, and in part by the bodily heat of the person himself. This assertion is to be qualified, however, by admission of effect from established or enforced currents of artificial ventilation, which may modify, or even reverse the natural flow.

The second popular error is that the carbonic acid of itself separates and falls to the ground by virtue of its greater specific gravity (as a pure gas), than that of air. This is altogether a mistake. Carbonic acid has a density as compared with dry air of the same temperature, of 1.524 to 1. It can be poured from one vessel to another as water is poured, but for all that, it "diffuses" or dissipates itself very rapidly, and when once diffused, no length of time effects the least settlement or separation. There will be no less carbonic acid at the top of a tube 100 feet high, than at the bottom. Carbonic acid, if colder than the air above it, will diffuse more slowly ; if warmer than the air near it, so as to be more close to the same specific gravity, it will diffuse more rapidly. Whisky will lay on the top of water without mixing downwards, but once mixed with water, nothing but distillation will separate the two liquors. In point of fact the carbonic acid emitted with the breath, is thoroughly, completely and inseparably mixed with the breath ; and the expired breath itself, as a whole, is rapidly, almost instantaneously absorbed and inseparably mixed with the air of the room.

A man vitiates more air than is needed for respiration ; an uncertain quantity of fresh air is both needed and vitiated in each minute by transpiration. A constant exhalation of carbonic acid transpires from the skin, by no means so large as that emitted from the breath, but probably one-fourth or one-fifth as great. The regularity of this transpiration nearly equals that of respiration. Accompanying this, it is probable that an absorption of oxygen corresponding to the equivalent of oxygen in the carbonic acid takes place. Experiments do not seem to have found the expired air from the the lungs has lost more oxygen than

the carbonic acid exhaled required, whence it follows, that the supply of oxygen to form the carbonic acid transpired, must be absorbed concommittantly. If now it be accepted, that air containing the proportion of carbonic acid existing in expired breath is utterly spent for the purpose of breathing over again, and if an allowance of air for transpiration be made, it is established that each person in still life, requires 580 to 600 cubic inches, or from 0.33 to 0.35 of a cubic foot of fresh air each minute, for perfect ventilation. Even this quantity can be reduced, as it is well known that in diving bells men do live, and do continue to work when the proportion of carbonic acid in the air of the bell rises to 8 per cent. instead of 4 per cent. as it is found in once exhaled air. Carbonic acid is an innocuous gas, quite harmless to animal life, except when it is substituted for oxygen in the air for breathing, and except also, in so far as its presence in large proportions interferes with the natural secretions from the lungs, and possibly from the skin.

Besides the carbonic acid, as one of the vitiations of exhaled air, there is known to exist a large proportion of aqueous vapor in the exhaled breath. Only $1\frac{7}{10}$ per cent. in volume of the air inhaled at 70 degrees, is vapor, while 5 per cent. of the same volume is exhaled at 20 degrees higher temperature. (By weight the quantity of vapor will have been increased as 35 to 100.) To this excess of exhaled vapor derived from the lungs or fauces, there is to be added a large, but very variable quantity of moisture imparted to the air of a room by insensible perspiration from the skin. The natural internal warmth of the body is very nearly 100 degrees Fahr., regardless of the heat of the external air, and comfort and health, even existence as a living animal, depends upon the abstraction of heat from the surface of the body, so that the heat generated in the vital functions shall not elevate that internal temperature sensibly for any considerable length of time.

This part of my argument was more fully discussed in the paper "on the relation of moisture in air to health and comfort," which was read by me before the American Institute of Architects at their meeting at Boston, in 1877. It was therein stated: "There are three means provided "for the healthful dispersion of animal heat. The first is radiation to "surrounding colder objects; the second, conduction to the atmosphere, "which, for comfort, must be sensibly cooler than the body; and the "third is, evaporation from the moist surfaces of the lungs and throat,

" and evaporation from the roots of the pores of the skin. The first of " these means—to the clothed person, at least, is comparatively ineffec- " tive, while the relative quantities of heat which may be eliminated in " any given time or locality, by the last two, will probably be found " nearly equal, in an atmosphere of about 70 degrees temperature and " of 65 to 70 per cent. humidity."

It may be assumed, as the conclusion from data established by many experiments and observations, that $1\frac{5}{10}$ to $2\frac{5}{10}$ pounds of water are evaporated each day from a person in still life, or from one not taking violent exercise, nor exposed to heat varying essentially from 70 degrees Fahr. This quantity of two pounds, gives, under the conditions previously accepted, about three and a half times as much vapor evaporated by insensible perspiration, as would be evaporated by breathing. If it be supposed that the moisture from insensible perspiration is to be absorbed and taken up by air of 70 degrees and of 70 per cent. humidity, so that this air shall become saturated with humidity, it then follows that no less than 4 cubic feet of air must be supplied for this purpose to each person each minute.

Aqueous vapor (which is merely the accepted name for steam in its invisible condition below the boiling point of water) is, like carbonic acid, an innocuous gas, quite harmless to animal life, except in so far as its presence in large proportions interferes with the natural secretions.

It would almost seem, from these statements as to the harmless character of respired gases, that the word vitiated was misapplied to exhaled air.

There is present in air, in general, a certain amount of gaseous impurities. Ammonia, sulphuretted hydrogen, and sulphurous acid gas, with numerous others of local derivation (especially near towns or cities), are found in very small quantities. So small that the hundredth of a per cent. is to be taken as a unit in measuring them. But besides these gaseous impurities, there always exists in air of inhabited regions very small quantities of floating organic matter, composed of fragments of organic origin, vapors of the same source, like odors, for instance, microscopic germs or living organisms, together with dust of minerals or metals, smoke, etc., forming an insignificant part of the atmosphere, nearly inappreciable by weight or measure, but of the greatest importance in effect upon the air of ventilation.

The dangerous vitiations of air by respiration or by perspiration, are

those which proceed from the decomposible organic matter exhaled or emitted. This organic matter appears to be carried to large extent by the aqueous vapor, although much of it exists as floating dust; and small particles of skin, fatty substances, bits of hair can be caught and identified by the microscope. The quantity of such organic matter is exceedingly diminutive as compared with any given volume or weight of air. Doctor Angus Smith (the only authority, but his authority is sufficient) concludes that not the one hundred-millionth part of its volume for pure air on high ground, or about the one five-millionth part in a crowded railway carriage, is organic impurities. Yet to a very small portion of this very small portion of air is attributed the danger from breathing vitiated air. In all probability the origin of disease can be found only in atmospheric germs of living organisms, which find the perpetuation of their vitality in the decomposible and decomposing organic matter suspended in the atmosphere, and which are disseminated through the agency of the same atmosphere.

The quantity of carbonic acid exhaled in a given time by any number of persons is nearly uniform, and also the proportion in free air is quite uniform, so that the proportion of carbonic acid present in any occupied room can be taken to represent very accurately the degree of vitiation from respiration. Not that the carbonic acid itself is dangerous or unhealthy; but by its presence in excess of the normal quantity, the organic matter proceeding from persons occupying the room, and the related unhealthiness can be estimated. The measure, however, is not a positive one, as a relationship to the degree of moisture in the air of any room is one of the conditions of the decomposition of organic matter, so that vitiated air laden with moisture may be considered more dangerous than the same air comparatively dry, and this regardless of the carbonic acid present.

This very long preamble to the real subject of this paper has been made because the writer felt it necessary to substantiate fully his fundamental propositions as to the absolute and demonstrable quantities of air needed for ventilation.

So far as carbonic acid and vitiations proceeding from the breath are concerned it is evident that only a little over one-third of a cubic foot of pure air is needed each minute, provided the entire volume of vitiated air be removed without mixture in the same time. So far as moisture or aqueous vapor emitted is concerned, about four and a half cubic feet per

minute supplied at 70 degrees and of 70 per cent. of humidity, will suffice to prevent the deposition, if the air be evacuated at 70 degrees and in the condition of saturation. While if it be admitted that the effluent vitiated air of the room has a temperature of 72½ degrees, its condition of humidity when carrying the same amount of vapor will be only 90 per cent. Whence four and a half cubic feet of air per minute (under these conditions of supply) is enough to remove all vitiated air from personal sources, to furnish perfectly fresh, pure air for respiration and to provide an *atmosphere* four or five inches thick around a standing individual, which *atmosphere* will ascend around him, and be supplied from beneath, at the rate of motion of about three or four feet per minute.

This proposition for the absolute ventilation of an individual has been stated in all its baldness to make its impracticable character emphatically evident. Men are not going to be ventilated in cases, even to secure perfectly fresh and healthful air. The purity of air in any occupied place can only be relative. The sole mode of removal of vitiated air possible is by diffusion and dilution. A much larger quantity of air will have been supplied or permitted to enter into a room, and will be removed or allowed to escape than is needed for the use of the persons occupying the room, during the time of their occupancy of the same; and the room itself will have a definite cubical capacity, and form an intermixing chamber for the fresh and vitiated air.

We have now passed all exact computation and come into a field of guesses and assumptions. With a definite supply of air to any room (which supposes in some way a corresponding efflux) a certain quantity of exhalations and emissions will eventually approximate to a definite ratio of the constituent parts of the air within the room. If it be supposed that twice the quantity of carbonic acid is admissible in a continuously occupied room, over that existing out of doors in fresh air, then ninety-five times as much air as is needed for respiration, etc., must be supplied to dilute the exhaled air. A proportion which gives about 32 cubic feet of air per person per minute, with a result of 0.0008 volume of carbonic acid present. If it be supposed that the hygrometric condition of the air is limited to an *increase* of 5 per cent. of the humidity in air of 70 degrees, then the absorption of vapor demands 25 cubic feet of air to each person per minute. These neat results from computation would be very satisfactory, if there were any grounds for the assumption of 8 parts in 10 000 as the exact ratios for carbonic acid and air in rooms,

or for acceptance of 5 per cent. of humidity in place of some other ratio, smaller or larger.

The whole matter, then, resolves itself into opinions as to individual personal comfort, and to observations upon healthfulness of some of the very few rooms and places where, for a period of time, more or less extended, a definite ventilation has been maintained.

It seems pretty well established, for rooms continuously occupied by persons, either in good health, or at least not subject to offensive disease, that 30 cubic feet of air per person per minute, if of proper temperature and humidity (temperature and humidity being considered to have related values), (and if adequately introduced and removed into and from rooms, which have a cubic capacity of not less than 1 000 cubic feet per person), will pleasantly, healthfully, and satisfactorily ventilate such rooms.

When one considers the various conditions comprised in this rule, he will comprehend how generally inapplicable the fixed rule of thirty cubic feet per person per minute becomes. The condition of the persons as to health, etc., will change the figures from thirty to sixty for surgical or obstetrical wards in hospitals. While for some diseases even the larger quantity will not remove offense, and for yet others no quantity of air can be named sufficiently large. Increase of temperature and humidity, for degrees and percentages above 70 degrees and 70 per cent. of humidity, begin to demand larger quantities of air for comparative comfort ; with 90 degrees out-of-doors, and 60 per cent. to 70 per cent. of humidity, even 60 feet per minute is not an excessive quantity of air, where 30 is named above.

The continuity of occupancy and cubic capacity are in some respects interchangeably related values. Where any room is to be occupied for a short time only, its cubic contents may be taken as so much fresh air, and deducted from the amount of air required for ventilating the same room for the same time. Thus let it be supposed the room itself has the cubic contents of 1 800 feet ; that one person alone occupies this room for an hour (supposing it to have been filled with fresh air at the commencement of the time), and that no fresh air is supplied during the hour; the degree of vitiation will only have reached the point which would, eventually, have been attained in a continuously occupied room, where 30 cubic feet of air had been regularly supplied each inmate. This almost self-evident proposition is of the highest importance in ven-

tilation. The homes of those in humble circumstances, and even of those who live in moderate ease, are made healthful, not by abundant constant supply of fresh air, but by frequent freshenings of the air of dwelling or sleeping rooms. No systematic ventilation, however well devised and constructed, however extensive its supply of fresh air, however regularly or judiciously operated, can afford to dispense with repeated displacement of the air of rooms, and substitution of entirely fresh air through open windows and doors, at times during all seasons of the year. This law of change of air taken in connection with a limited supply during time of occupancy, applies directly and at once to the halls of audience, the ventilation of which is the theme of this paper.

In all civilized countries, people congregate in churches, halls, or theatres for devotion, instruction or amusement. The ends of government require legislative and council chambers and court rooms which have at times crowded sessions. There are thousands of rooms in this land, and in other countries, in which crowds are gathered and often packed for sessions of one to six hours on the average, with occasional sessions, in some legislative halls in particular, of twelve and sometimes more that twenty-four hours. Anything may be called tolerable that is tolerated, anything may be esteemed endurable that is endured. Churches, halls, schools, theatres, State houses, court rooms, etc., are rendered tolerable when judicious care is taken in changing the air after a session, and in having fresh air in the audience rooms, at the commencement of the same. They are endurable—not only can little illness or actual disease be traced to them as places of origin, but on the whole, the audiences, accustomed or habituated to the closeness of the air which accompanies any lengthened session, cease to notice what would be excessively disagreeable to a new-comer into the confined room. People do not willingly find fault where there is apparently no remedy.

Perhaps the most striking example of this salutary effect of occasional change of air as a substitute for ventilation by constant supply, is to be found in our American railroad cars, where, in cold weather, the least of regular supply is furnished to largest number of persons temporarily crowded into the smallest space. To the outsider the heat becomes intolerable ; to the insider it is more tolerable than any draft of fresh, cold air.

To the chemist, the air is found "vitiated" to the extreme, both with carbonic acid and with vapor of water, while it is laden with organic im-

purities that are hastening towards the condition of offensive decomposition. The unhealthful condition of the air, in thousands of cars on any day during six months of any year, cannot be questioned. And yet no serious illness that can be attributed to the want of ventilation, is found amongst the tens of thousands of passengers, and it is well known that the conductors, brakemen, and others connected with the trains, who live in and out of the cars from day to day, are healthy beyond the healthiness of most other men.

Comfort is found in warmth. Whatever supply of fresh air be given, not the slightest sensation of cold must be appreciated from the current of fresh air by any occupant of a room. There is only one exception to this dictum, and that is when a person having come to a sense of oppression from the air of a room (a sense which is almost invariably one of heat and not of badness), voluntarily endures the admission of fresh, cold air upon himself. Such a person will be more likely to enjoy a blast from an open window when the external air has the temperature of zero, than to endure a gentle current of four or five feet per second, of air at 60 degrees to 65 degrees, and 45 to 50 per cent. of humidity. The requirements of ventilation are not positive. Those of comfortable warmth are immutable facts. The air of any room may have become much vitiated, and even offensive, and if its temperature be kept down to the point of comfort, most persons will deem such air to be fresh within the desirable degree of purity, while an overheated room is apt to be pronounced to be "filled with bad air," although the air may be as pure as is attainable.

The popular appreciation of ventilation is founded upon effluvia and heat. Effluvia may proceed from two sources : first, from the decomposition of organic matter exhaled or emitted—a very short time is needed for this decomposition to become apparent—and second, from odors which emanate from the person or clothing of those occupying a room, whether the odor be offensive or defensive. In either case effluvia, when marked as pervading a room, or any portion of it, is a legitimate evidence of inadequate ventilation. The effect of odors, however, on the senses is very imperfectly marked. A habitude is established, and nine persons out of ten of an audience do not realize the degree of vitiation which has been reached by gradual steps during a session, and at the end of the same, when passing to the outer air, the change of temperature will not allow the change of quality to be perceived. Unless one has had occasion to enter the hall during the sitting he will never know the

air had become impure. Heat becomes, therefore, almost the sole standard by which ventilation of halls is judged. The overheated condition, especially of the upper portions of halls, obtains the designation of closeness, and is generally submitted to the limit of endurance, at which point some window near by is opened, greatly to the discomfort, in cold weather, of those on the floor of the hall, and little to the relief of the overheated portion of the room.

Except in very cold weather, crowded halls do not require the supply of much heat. Many halls, with corridors and passages on one, two or all sides, especially auditoriums of theatres, require no more than to be warmed to a comfortable temperature before the audience collects, after which the heat from the persons composing the audience will more than supply what heat is lost at the windows or walls. For ventilating a hall in such case it becomes necessary to introduce air of lower temperature than that of the room. The problem, then, is how to introduce and distribute cold currents of air amongst a crowded audience without producing the sensation of cold to any one of them.

The air supply demanded may not be strictly cold. Its desirable temperature may rise considerably above the proper temperature of the room, and yet it will, in currents, be perceptibly and sensibly cold.

The feeling of cold from currents of air proceeds from two sources: First, the abstraction of heat in warming the air itself, and second, from the absorption of vapor by the air, which vapor will have been formed at great expenditure of heat from the natural moisture of the skin. "The quantity of heat taken up in the vaporization of the moisture of the skin by dry and cold air, compared with that abstracted in warming the air, is so great, that the heat imparted to the temperature of the air becomes much the least in the ratio. Thus air at 35 degrees and of 70 per cent. humidity, demands nearly the same quantity of heat, to warm it to 70 degrees that is requisite to vaporize the moisture which will raise the humidity to 75 per cent. at 70 degrees.* It is very nearly correct to assert that the cool sensation from a breeze in summer proceeds entirely from the evaporation of moisture thereby induced. A current of saturated air at 100 degrees will neither remove heat by contact nor by induced evaporation, and is consequently incapable of producing a cooling effect; while as the temperature or the degree of humidity is sup-

* Vide addenda to paper "On the Relation of Moisture in Air to Health and Comfort."

posed to fall, the same velocity of current becomes first a pleasant, cooling one, and next a decidedly cold one. With a high temperature and dry air the cooling effect of a current (even at 100 degrees) may be pleasant to the sensation, but will be attended by sun-burning (even without exposure to the sun), and blisters will be produced by the excessive deprivation of moisture, from the cuticle or surface of the skin. With 80 degrees of heat and a high dew point a strong breeze is not unpleasant, nor likely to be injurious, after the person shall have acquired some accustomed habit of body to endure it; but at 70 degrees and a low dew point, which is the only possible condition of heated air in mid-winter, the annoyance of a current of even five feet per second and its unhealthiness are positive facts." *

It is proper that I should advert at this point in my discussion, to the marked differences of the variations and requirements of warming and ventilating that exist in this country from those which are found in England or France. The subject has been considered in the paper "On the Relation of Moisture in Air to Health and Comfort," but it may be now again referred to, in support of the view that American practice should be directed to meet the special requirements of American conditions, and not to conform with other requirements, however well established in themselves. As was set out in the paper "On Moisture in Air," it seems at first inexplicable to an American how the statement can be made by foreign writers that 56 degrees to 62 degrees Fahrenheit are comfortable temperatures for living rooms, when in cold weather he is scarcely warm at 70 degrees, and in mid-winter is not overheated at 80 degrees, although clad at the time in the thickest of underclothing. The fact is that the deprivation of heat from the person is greater from the evaporation of moisture than from radiation or convection of the air, and the hygrometric state of the atmosphere has so much influence, as to make a temperature of 56 degrees in Ireland, the West and South of England, or in Normandy, sensibly as warm as 80 degrees in Canada or Minnesota at about the same season of the year.

All mankind complain of the weather, and an Englishman especially. But there are in England, eight months of the year, when the thermometer ranges between 40 and 60 degrees in the shade (and there is very little sunshine), with a dew point so high that it is a pleasure to

* Quoted from a paper by the author, on the Ventilation of the Hall of Representatives, Washington, 1876.

exercise in the invigorating air; one month of 60 to 80 degrees, and three months from 25 to 50 degrees. While in Northern America there is scarcely one month (or 30 days) with the average temperature of 50 to 70 degrees (temperatures which, from the difference in humidity, correspond sensibly to 40 to 60 degrees in England), and there are about three months from 75 degrees to 90 degrees, three months of 30 degrees to 50 degrees, and five months of excessive variation of temperatures from zero to 40 degrees or 50 degrees, these last five months having about 30 days of warm weather at intervals. During the three hot months, and also during the five cold ones, open air exercise to those whose avocations are generally within doors, is almost impossible. Any one, who is called upon to endure the fervid summer heat, or who will habituate himself to the inclemencies of our Arctic winter, will not suffer great discomfort therefrom; but the weak and the tender, the workman of the factories, the tradesman of the shops, the merchant in the counting house, the student at the desk, cannot acquire the endurance or the habit, and must shelter or warm themselves.

It follows that the ventilation of halls in England for eight months of the year is simply the quiet introduction of a given quantity of external air, little or no increment of heat being necessary, and for three-twelfths of the year the similar introduction of air, heated 15 degrees to 20 degrees. There is one month of altogether open windows; but except on a few very stormy days, there are few times when relief from overheat or closeness in a room, cannot be obtained without serious discomfort, by partial or controlled admission of external air, directly from windows. The small addition of heat demanded at any season, and especially for the most of the year, prevents the adoption of our system of ventilation by means of warmed currents of air. The use of the levity of the entering current ceases to be available, when that current must necessarily be only very little, if at all, higher in temperature than the room itself. On the other hand, the operation of an exhaust system, where an exhaust shaft or fan is made to remove air from the room, becomes eminently feasible, when the general conditions are such that the outer air may be taken in freely, at any provided or arranged inlet, without discomfort from its want of heat. The great support of the exhaust system for American usage is derived from English authority and example, together with its applicability to ventilation for the American single month of the year, of 50 degrees to 70 degrees, when closed

windows and a supply of unheated air is the requisite for occupied places.

Our season of open windows is longer than that of England, but it is also much hotter, and we are constrained to some forced supply of air during the hot season to render audience halls tolerable. Our term of mean temperature is so brief that its especial consideration may be neglected for audience halls; but for asylums or hospitals this term must be adequately provided for. The real point of discussion is how to warm with an average temperature outside of 25 to 30 degrees to the inside temperature of 70 degrees to 75 degrees, and how to supply with the warming, sufficient air for breathing and for the preservation of relative purity.

There are two respects in which ventilation of halls becomes easier in America than in England. The greater humidity of the English climate prevents the dispersion of exhaled vapor with the same rapidity as with us, and exhaled vapor is laden with organic impurity on the verge of decomposition. Only a very few minutes are required for surcharged air at the temperatures usually existing in close rooms to become offensive. The fœtor of a long occupied hall in England is distinctive to an American and unapproachable in a dryer climate. In another regard we have, in the court rooms, theatres and public buildings in general in America, the advantage of superior cleanliness in dress and person for a considerable portion of the audiences. We have comparatively no ower order to ventilate against.

Returning from the long digression of comparison of American with foreign requirements, to the consideration of absolute requirements and practical demands. The following has been established by the previous argument, that for the support of life, each person must have one-third to one-half a cubic foot of fresh air each minute. That for the conservation of temperature to the point of comfort, each person supplied with air at 70 degrees in its usual condition of summer air in America, must have four to four and a half cubic feet per minute. That to maintain the freshness of air in a continuously occupied room, so that it shall be pure to the sense of smell—a condition which is found to correspond generally to the presence of 8 parts of carbonic acid to each 10 000 parts of air, about thirty cubic feet of air, per person per minute, is requisite. It has been shown also how audience halls, without systematic ventilation, or at best supplied with very limited quantities of air, are, if of

adequate cubic content in comparison to the number of persons present, and if occupied only in short sessions, and if judiciously supplied with fresh air between the sessions, relatively healthy, comfortable and acceptable to the persons attending them. The point for enquiry which now follows is, what is the practical limit for quantity of air to be *systematically supplied ?*

The proposition before established, that the cubic contents of the hall can be reckoned as part of the supply itself, by taking the number of minutes the hall is occupied by a certain number of persons, becomes now of importance in fixing the limit for momentary supply, when the average length of session can be assumed. But this is really of less importance than would appear from mere statement. On the whole, in audience halls, the cubic capacity per sitter, will be found to be from 200 to 300 cubic feet, or only 6 to 10 minutes supply of air to each person, where the final relative purity is to correspond to a supposed regular supply of 30 cubic feet per minute. If this cubic capacity is to be taken in addition to any regular supply for a given length of time, then if 100 minutes (1 hour, 40 minutes) are taken as the length of the session, two to three cubic feet of air per minute becomes available as an addition to whatever is supplied.

The practical difficulties in ventilation of halls which effect the quantity of air to be supplied, are those of introduction and of distribution. The difficulty of introduction is perhaps the most serious trouble. Dr. Reid's proposition for a perforated flooring, would seem to present a satisfactory solution, and it is questionable if justice has been done the reputation of the scheme by the public, for the method continues in operation to this day, with twenty-four years' service at the Houses of Parliament; although embarrassed in its action by singularly unmechanical and inefficient apparatus for warming and supplying the air. It cannot be claimed, however, that the construction of a sub-hall for equalization of pressure, will meet the approval of architects or builders in future, and Dr. Reid's effort will probably remain as an example, rather than be accepted as a model. But Dr. Reid was for a whole life time of arduous labor, an intelligent and careful observer of the requirements for the ventilation of audience halls. As the result of his study he concluded, and he expressly states his conclusion as with diffidence, that 10 cubic feet of air to each individual would suffice to properly ventilate a hall. His great effort

was to arrange to supply this quantity in such way as should be at once effective and imperceptible to an audience. Much of his want of success laid in the imperfections of his mechanisms, in the coils or heating surfaces, and in the fans or means of impelling air. Some of it laid in the effort to regulate the audience as well as the ventilation. His life-long difficulty was found in the establishment of local currents engendered by his imperfect apparatus, and from the sensation of cold which such currents produce.

Systematic supply involves arrangements of ducts and passages by which the outer air, from some chosen point, shall be transported to certain desirable mouths of delivery or inlet registers. The dimensions to be given these ducts or passages are absolute and positive ones, when the quantity of air to be moved shall have been established by the number of persons and their supply, and when the velocity of movement of air is determined or accepted. The velocity of movement is limited on the one hand by the motive power applied to impel or effect it, that is, by the expenditure of force demanded; which means in the end, whether impulse by fans and engines, or a draft from a heated flue be used, expenditure of fuel; and on the other hand by practical dimensions accepted in construction of the ducts or passages.

In figures, ducts for forced ventilation must suppose currents of from 600 to 1 200 feet per minute, with some allowance of sectional area for branch ducts, which shall admit a less velocity of flow through them; while ducts for currents induced by exhaust shafts, or produced by the entry of heated air, at the usual temperature of steam heated currents, will have a usual velocity of from 150 to 300 feet per minute—sometimes, under favorable conditions for making a draft, rising to 300 or even to 600 feet per minute.

Systematic supply involves also the heating of air to be supplied, in an extreme case, from 5 degrees to 10 degrees below zero up to perhaps 75 degrees, in such extreme case of cold weather. Ventilation is not attained except at cost for fuel, and a reasonable expenditure in this regard will meet approval when restricting the amount of ventilation to the necessities for health. The heat *will* in all cases be that of comfort or the *system* will be discarded.

Finally, the writer has sought with diligence and study to determine from irrefragable data, the exact quantity of fresh air that should be supplied to each person of an audience per minute, and he now finds

himself compelled to admit that no such data exists. That the quantity must be taken to have an arbitrary value founded on economic and structural, as well as upon medical and chemical considerations ; that this value must have its authority from its general acceptation by the community or by its general acceptance by investigators, who will have considered the question from all points,

It would seem that for audience halls occupied for sessions not exceeding two or three hours duration, Dr. Reid's value of ten cubic feet of air per minute, is all that should be arranged for when planning such halls—all that can be judiciously urged in the accomplishment of ventilation in view of the cost in fuel and apparatus, quite sufficient to meet the physiological issue, and so large, that it ought to be accepted from the medical point of view. This quantity might be referred to the maximum seating or holding capacity of the room to which it should be applied, when its partial occupancy would go towards increasing the general supply. And it should be referred to the coldest weather heating power of the accompanying heating apparatus, so that in case of emergency of lengthened sessions in milder weather, and in hot weather, the quantity could be materially exceeded. When a forced ventilation by means of a fan is adopted, the flues and passages should refer to a winter ventilation at half speed of the summer one, and the quantity of summer ventilation would then become twenty cubic feet per person per minute. An amount of ventilation which, with open doors and windows, would, if the ventilating currents are suitably distributed amongst the audience, prove ample to give all the comfort possible to a crowd gathered in hot weather.

For audience halls in legislative buildings, there is a propriety in adhering to the larger quantity of air, which has been mentioned as needful to preserve the sensation of pure air to the smell in continuously occupied rooms, to wit, thirty cubic feet of air per person per minute. As before, this quantity should be referred to the maximum attendance in any hall, and the capacity of the heating apparatus be referred to the coldest weather for such quantity, so that the forced ventilation should be adequate to give a double supply in mid-summer.

In the mind of the writer there can be no question whatever as to the direction of ventilation in a hall. A man lives in an ascending current of air—he is enclosed in one. In a crowd, without ventilation, a circulation takes place; in some way the roll of air which rises above

one's head is replaced by cooler air sucked in sidewise at the feet, or downwards, between the persons who form the crowd. If fresh air can be, and is, introduced imperceptibly at the floor near the person who needs it, the rising current supplies, nearly unmixed by diffusion, the air for respiration, while the vitiated air is swept upwards with the advantage of its levity as well as of the current of supply. A downward system of ventilation, on the other hand, where the air is supposed to be abstracted at the floor, near to the individual, supposes a thorough admixture, mechanically, of the respired and vitiated air with the descending sheet of fresh air. Within any hall where the air enters at the top, there could scarcely exist any fresh air whatever, while the degree of vitiation would increase downwards, until the occupants of the hall would breath and live in the vilest air possible for any given supply of fresh air.

There is also another matter to be thought of in ventilation of halls—the ventilation of the gas lights, and besides this ventilation, the removal of the heat they generate. The ordinary gas burner consumes 4½ cubic feet of gas per hour. Each burner may be taken to demand 2 700 cubic feet of air per hour or 45 cubic feet of air per minute, when the temperature of the gases of combustion, including the 45 cubic feet of air, becomes, for open burners, as high as 99 degrees, and for Argand burners possibly as high as 128 degrees. In an upward ventilation the gas lights present little difficulty, as the air for ventilation of the persons composing an audience will commonly exceed in quantity the greatest requirements for gas burning. The vitiations arising from gas lights are very objectionable when the attempt to introduce air strictly at the ceiling is made. The figures given here as to the requirements of gas lights will allow provision to be made for them in arranging the ventilation of halls. The radiation of heat from gas lights of a brilliantly lighted room becomes not only an important addition to the heat of the air, but also to the heat of the occupants of the room, independent of its temperature in some degree. This effect of gas light is sufficient to reduce the desirable average temperature of a gas-lighted room, some two degrees to five degrees, and the necessary temperature of admitted air should fall off in like degree. No amount of ventilation will make it comfortable to sit near the great chandelier.

It is a source of great gratification to know that the electric light has reached that point of development where it has become available for

lighting audience halls. The practicability of electric lighting at present is found in the production of large quantities of light. As the introduction of gas light led to the use of much greater illuminating power than was obtainable by candle lighting, however numerous and sparkling the candle lights may have been displayed from reflecting sconces or chandeliers hung with lustres in old times, so the electric light also overpowers the gas light wherever substituted, to much the same extent. The electric light is the nearest possible to the natural one of the sun. Properly arranged, to avoid distinct shadows, the correspondence to a carefully shaded room with ample mid-day light can be secured. Lighted from above, a complete avoidance of objectionable glare can be effected. Colors will have natural tints and values, and the gratification of our most delicate sense, is not the least of promise in the perfection of electric lighting.

The vitiation of air by the electric light, arising from the slow combustion of the carbon, is too insignificant to form any element in considering the ventilation. For an equal quantity of light, there is generated seven hundred times as much carbonic acid in coal gas lighting as in electric lighting. There is a small amount of vitiation from the electric light in the form of nitric or nitrous vapors, which may or may not accompany coal gas burning to equal extent where equality of light giving effect is made the standard of comparison. But this quantity of vitiation is also utterly harmless, in the volume of air demanded for ventilation of the number of persons who are to derive their light from any given electric source. The heat effect of electric lighting is as favorable to the ventilation and comfort of audience halls as any other advantage presented. Thus, the same light-producing capacity gives thirty-four times as much heat for gas lighting as for electric lighting with equivalent light values, as the most unfavorable showing of the electric system, supposing all the force expended in the electric arc is transformed into heat. Furthermore, the superior safety of the electric light as regards danger from fire, is not the least of its recommendations when enumerating advantages. At the present time the cost of electric lighting, with liberal allowance for use and deterioration of apparatus, is about one-half that of gas lighting, when the same quantity of light is supplied; but in view of the superior lighting usually practised when the electric system is introduced, the two methods approximate to the same cost generally.

Resuming the discussion of ventilation again. It must not be accepted from the foregoing remarks on downward ventilation that the removal of air at the floor of a hall is wholly impracticable. In rooms of limited floor area, like school rooms, an arrangement for supply and removal of air in conformity with the great natural circulation which occurs in all heated rooms, is likely to prove successful in those conditions of the weather which demand warm rooms. And as has been shown in our climate, there is but about one month in any year in which closed windows are desirable, *without an attendant supply of heat to the room*, it follows that such school rooms may be effectively ventilated during the eight months when our temperatures vary from zero to 40 degrees or 50 degrees, that is for seven-eighths of the time when windows are closed. By judicious manipulation of windows and of eduction flues and their registers, the ventilation during the one month of closed windows without fire may be ameliorated, if not made altogether efficient.

Again, in churches and lecture rooms, where the economy of apparatus and of operating is esteemed superior to ample but expensive ventilation, the systematic provision and removal of much smaller quantities of air, than have here been shown needful for desirable purity may accomplish much improvement in the direction of relative purity. The habitual method of warming a church building in America is by means of several hot air furnaces, placed in the cellars underneath, as sources of heat. These furnaces having usurped the functions of the close stoves, with long lines of smoke pipes, which were formerly a peculiar feature of the "meeting houses" of our fathers. The furnaces have just about the same heating capacity, and the distribution and circulation of the heating currents within the walls of the church is effected in much the same way. When actively employed in warming the church by means of furnaces, there is a supply of fresh heated air, considerable, perhaps, in itself, but inconsiderable, at its largest quantity, to the wants of ventilation of the numbers present. The control of temperature of the heating currents is very limited, the lowest temperature being commonly about 180 degrees, while the highest, often demanded in the coldest weather, rises to quite 300 degrees, and sometimes above this point; and the control of warmth in the church itself is obtained by closing or opening—registering off—the hot air current. In ordinary cases, the registers are shut soon after the commencement of any session, and if

the room be well filled, the heat of the persons present (especially at evening meetings where gas lights increase this heat) causes it to become overheated long before the end of the hour, or hour and a half, of usual session.

The equilibrium of temperature in such a room, is established solely by the cooling effects of the walls or windows, downwards along which there falls a sheet of cooled air (augmented in cold at the windows by leakages inwards at the bottom of the same), a sheet which flows inwards towards the register openings, and is directed upwards with the flow from them ; or when the register is closed off, the sheet forms part of the current of personal origin rising in the middle of the room. This roll of circulation goes on continually, and at some degree of elevation of temperature at the top of the room, the lower strata reaching to the height of above a gallery sometimes, will be found to have attained some uniformity of heat. In fact, when filled with heat, as the furnace constructors denominate it, there will, in a church building of 35 to 45 feet in height, be less than 10 degrees difference between the floor level temperature of air and that taken 20 to 25 feet above such level. No large ventilating shaft can be taken from the upper part of such a room. Even the small opening to remove the gases of combustion of a chandelier disturbs the circulation of heat and intensifies the cold descending currents near the window, besides accelerating the leaks of cold air at the cracks; so that the ventilation of churches thus heated, is practically limited to what leaks *out* of heated air, at or near the top of windows, and what leaks *in* of cold air, at or near the bottom of the same. A systematic leakage, which on windy days is modified by all leaks *in* at the windward windows, and all leaks *out* at the leeward ones. Now a kind of semi-ventilation of a church thus warmed and arranged can be effected by removal of air, at or near the floor, by means of ducts connected to an exhaust shaft ; all of which will become operative if the currents from the hot air registers have been augmented to meet the requirement of air, by tempering the heated currents with direct currents of cold air, to desirable heat and quantity. Here it is seen that a downward ventilation, under conditions, may effect a good purpose to a certain extent.

It will not be attempted at this time to argue fully the advantages of the method of supplying air for ventilation by impulse through mechanical means—the superiority of forced ventilation, as it is called. This mooted question will be found to have been discussed, argued and

combated on all sides, in numerous publications, but the conclusion of all is, that if air is wanted, in any particular place at any particular time, it must be put there, not allowed to go. Other methods will give results at certain times or seasons, or under certain conditions. One method will work perfectly, with certain differences of internal and external temperatures, while another method succeeds only when other differences exist. One method reaches to relative success whenever a wind can render a cowl efficient. Another method remains perfect as a system, if no malicious person opens a door or a window. No other method than that of impelling air by direct means, with a fan, is equally independent of accidental natural conditions, equally efficient for a desired result, or equally controlable to suit the demands of those who are ventilated ; which last requirement, it will be shown further on, is more essential than to meet their necessities.

To many people it is a favorite belief that ventilation should be in some way effected by a natural process. Windows and doors and open fires are the limit of artifice to be endured, houses being *presumed* in lieu of caves. There may be a fireplace with its chimney in the category of *natural* apparatus, although this was as artificial and as abstrusely ingenious to our ancestors of five or six hundred years since, as the best steam or hot-water heating apparatus is to us to-day. Perhaps to quote from my former paper on moisture in air will be the best answer to such persons: "Clothing, houses and fires are the means by which mankind is enabled to inhabit the earth. It is an artificial existence for an animal whose natural life would otherwise be limited to a small belt of the torrid zone, where the temperature never falls below 80 degrees, nor rises above 100 degrees." Fresh air will not be supplied naturally to a person in an audience hall, as one obtains it on a mountain top, at the sea-shore or upon the deck of a vessel. Neither the currents nor the temperatures of the healthful breezes are admissible in the processes of *ventilation*, so that the natural supplies cannot even be simulated artificially. To meet the demand for health and comfort in the natural gregation of men, which is one of the conditions of advancement in civilization, ventilation and warming must be effected with unnoticable means and yet with positive results. Success in ventilation of halls can only follow the complete adaptation of mechanical appliances and apparatus, as well as of structural arrangements, to the ascertained wants and requirements of the individuals composing an audience. In all mechanical appliances that is sim-

plest, which most positively and directly effects the purpose in view; and in this matter of supplying air it may be claimed that the process of impelling it, when and where wanted, is at once the most certain and efficient, and that the fan (in its form of a rotating wheel with vanes for large uses) is the simplest and readiest machine for impelling air.

It will not be attempted at this time to discuss the theory of Rotary Fans. The fan itself will simply be accepted as one of the recognized appliances in the construction of ventilating apparatuses, available with other mechanisms in established forms and defined types for American practice.

The fans most generally in use for the ventilation of large buildings in this country have been derived, in all essential particulars of conformation, from those designed by the writer for the United States Capitol at Washington in 1855 and 1856. These particular fans were based upon a type given by M. Combes (in his "Aerage des Mines"), where the fan blades or vanes were placed upon the face of a disc; and the fan itself thus constructed, was located in front of a circular opening in the wall of a building, the wall forming one side of the zone of blades, in opposition to the outer edge or face of the disc, which formed the other side. In this construction, no case whatever is demanded for the fan, which receives its air through the central circular opening in the wall, and delivers its air at all points of the periphery into a large but close room; from which room the ducts for conveying air, branch in any desired direction.

The heating and ventilating at the United States Capitol was under the charge of Maj. Genl. M. C. Meigs (then Lieut. U. S. Engineers), who selected this type of fan as presenting certain structural advantages for its employment. The study of the conditions of fan construction which was devolved upon the writer, led to some modifications in the forms of blades, etc., as accepted by M. Combes, with which changes these fans were employed in the ventilation of the United States Capitol buildings. More recently the disc type has been departed from, but in other respects the proportions of the Capitol fans have been followed and have now become established in general practice. It was a recognized necessity that a fan should be reduced to its least practicable dimensions, and the most cursory observation showed that the passage of air through the fan itself was an accelerating flow, whose least velocity should be, that at which the entering air ap-

proached the inner edges of the blades, and its greatest velocity should be, that at which the escaping air left the tips of the blades. The action of the blades being to give an accelerating velocity, to be mainly derived from the increase of velocity of the blade surface as it became further from the centre. It followed as a resulting consequence, that the area of any cross section of the passage through the fan (any one of which will be formed between the disc and wall or case side, and between any two blades), should reduce in proportion as the air accelerates, and that the air should thus be kept in contact with, and be acted upon by the blades as the source of impulse. These propositions gave, for instance, where the disc of the fan was taken to have a diameter equal to one, the diameter of the mouth or central opening becomes seventy-four hundredths; the width of the fan at the mouth becomes seventeen and a half hundredths; while the width at the periphery becomes one-tenth. The number of blades was found (by experiments as to most efficiency with several different numbers), to be about sixteen; a number giving the section of the several passages formed by blades, disc and wall, most nearly a square one, or most nearly that section of a duct or passage, where the sides offer the least resistance to flow of a fluid.

The advantages in effectiveness or economy in power over other fans as before made, with small central opening and great width of vanes in direction of the axis, is not very considerable; 10 to 15 per cent. of higher useful effect is all that can be claimed, when 55 to 60 per cent. is usual; but the advantage of obtaining at least twice the capacity, simply by enlarging the mouth and by increasing the number of blades to suit their reduction in length, is of high importance when room to place a fan in a building, is frequently one of the troublesome questions to be met. Since 1856 probably 150 of these fans have been put into use in various hospitals and public buildings. The principal modification adopted has been the frequent use of blades on both sides, with the same disc construction; sometimes (for fans of four to eight feet diameter) with iron in lieu of brickwork cases. This last arrangement presents some difficulties in the entering air passages, but it reduces the diameter of a fan to do any given work, to seven-tenths that of a single disc fan.*

* The only full published account of this fan is to be found in the proceedings of the Institution of Civil Engineers, 1869-70, but the publication in the catalogue of apparatus of the Pascal Iron Works, Class IV., 1863, and subsequently, gives essential particulars, and has perhaps much aided in the introduction of the fan. The catalogue was compiled by the writer of this paper.

In general these fans are driven by a directly connected engine of suitable size ; sometimes a belt and pulley is used for transmission from an independent engine. This last condition, that of independence from other uses, is desirable for hall ventilation, so that an economy of working may be practiced to meet the condition of occupied and unoccupied halls ; but for hospital ventilation it is about as well to drive the fans from the general source of motive power, always indispensable in large hospital establishments.

Boilers and all their appliances, engines, etc., are not distinctive or peculiar to ventilating or heating apparatuses, and call for no mention in this paper as to methods of construction.

The steam heating apparatus in all its details, as used in America, is peculiarly American, especially the apparatus of small wrought-iron tubes, which had its origin at the hands of the late Joseph Nason, between 1840 and 1850, and has now become one of the established industries of the land, employing a whole class of workmen known as steam fitters, and supporting large establishments, devoted entirely to the manufacture of and trade in tubes and fittings.

The little step in mechanism which is the foundation of this art, is found in the use of the tapering thread on the end of the pipes, wherewith a perfectly staunch joint is cheaply provided and made. It is curious, that with over forty years practice in steam fitting, until no workman in iron regards this taper screw joint as other than the matter of course way of making a pipe joint, with this established habit of workmanship, no description or notice of the tapering screw is published in any textbook, nor have its peculiar advantages been considered by any general writer on constructive mechanism. The great importance of this improvement in making the joints of steam pipes to this industry of steam heating can scarcely be over estimated ; but it was not only in this particular but in many others of detail, that Mr. Nason's ability as an inventor and adaptor was shown in the apparatus; while super-eminent above this he was at once the best informed of his day on the theory, and the most able in the practice of steam heating. Under his tuition the whole trade originated—ten or twelve years since it was possible to trace the descent or pedigree of any concern in the business to the original source—at this time, the growth of the business going to a third or fourth race of firms or of workmen, precludes the following out of the continuity, although it certainly exists. The business, however, has been, and is dependent

upon the development of mechanical ingenuity, mainly from Joseph Nason, who gave form to the globe valve, originated and derived or adapted from the practice of hot water heating apparatus in England—either the Perkins' high pressure or the green house low pressure system—all the essential details, which now form parts of usual every day construction in the United States. Curiously, steam heating as practised here, is not yet fully known or used in England or France, and but little more known in Germany.

The writer of this paper, became connected with Mr. Nason in 1848, when he was employed to superintend the construction of tube works at Malden, near Boston, for Messrs. Walworth & Nason, and from that time until now he feels able to claim some standing in advancing the industry of steam heating. It will have been noticed by most who have to do with construction, that the form and shape of valves, elbows, tees, and of details generally employed or made any when in the country, are strikingly similar. In fact they are universally copies, following exactly the designs and proportions, as to sizes and thicknesses, which the writer established and published in the catalogues of the Pascal Iron Works, nearly twenty years since.

From this general acceptance of the types of steam heating apparatus and its component parts, any one is at liberty to specify a definite construction of coils and mains, with a correspondence of detail. He can measure and plan to use any arrangement of standard articles, selected from any trade catalogue of a steam heating establishment or firm, and feel sure that the work will have been so arranged that it can be bid for in open competition, and that he is getting the best work or details of work, to effect his purpose in his own way. More than this, it may be regarded as tolerably sure that any patented improvement of detail or method, is inferior to what can be procured and supplied from regular traders.

In the arrangement of ventilating and heating apparatus for Halls of Audience upon the foregoing type, a few figures of proportions required may here be stated :

It having been accepted what number of people are to occupy a certain hall—taking the maximum number—the total quantity of air needed each minute, will be derived by a simple multiplication of this number by the quantity per person, per minute, which the occupancy of the hall demands. That is, for a hall occupied by occasional sessions of one or

one and a half hours, say ten feet, while for a legislative hall for frequent long sessions, thirty feet may not be too large, while proper judgment should determine intermediate values for other conditions of occupancy. The figures of total quantity of air needed each minute being determined, the sectional area of the duct, near the fan, is got by dividing this figure by 600.* Now, this area is simply that of the periphery of the fan multiplied by its width, and as the width of the single fan at the periphery is = one tenth diameter, it follows that the area of outlet is $= \pi D$ (= circumference), multiplied by $\frac{1}{10}$th D (= width) $= \pi D^2$ divided by ten. Taking the value of π (= ratio of circumference to diameter) ; making the division, and extracting the square root from the figures given, it follows that D (= the diameter of the proposed fan) = 0.073 times the square root of the number of feet of air to be moved each minute. This rule can be expressed more simply in algebraic characters, as follows :

$$N q = Q \; ; \; \frac{Q}{600} = \frac{\pi D^2}{10}$$

Where N = maximum number of persons to be supplied with air for ventilation.

" q = least quantity of air per person, per minute, in cubic feet.

" Q = total quantity of air to be supplied, or the least quantity in cold weather, also in cubic feet.

" $\frac{Q}{600}$ = sectional area of duct near fan, in square feet.

" D = diameter of single fan, that is of a fan which carries its blades and receives its air on one side only, in lineal feet.

" π = ratio of circumference to diameter.

Reducing the above equation to give the value of D, then :

$$D = 0.073 \sqrt{Q}, \text{ nearly.}$$

and for a double fan or one receiving its air on both sides, then :

$$\mathfrak{D} = 0.053 \sqrt{Q}, \text{ nearly.}$$

When $\mathfrak{D}$ = diameter of double fan, or of one carrying blades and receiving air on both sides of the discs, in lineal feet.

The inlet or suction air duct or passage to a fan, should have, as an absolute necessity to supply the air, 1.4 times the area of the outlet or distributing duct. To compensate for resistance of air in passage along the ducts and yet to preserve the smallest efficient areas of distributing ducts

* 600 feet having been stated previously as the desirable rate of flow of a forced current in a duct per minute.

and branches, the sectional area of such distributing ducts or branches, at any given distance from the fan, should be increased over what is derived from $\frac{Q}{600}$, by adding 0.0025 times ($\frac{1}{400}$) for each foot of distance, and there is required a constant addition of 0.25 ($\frac{1}{4}$) a square foot, which becomes a necessity to meet the great resistance of small passages. The area of a main duct at any given distance from the fan, should be formed by computing after this method—the area of *each* branch, which may be considered as *trumpet shaped or expanding from* the fan to the point of bifurcation (from which point the *branch* may be deemed parallel), and this area is to be used when summing up an aggregate of total area of cross sections at such distance.

It may be needful to call attention of those who may plan a ventilating apparatus, that the air-ducts must be exclusively devoted to their purposes and should not be used, or even made so as to be available for passages. They may be employed for the lines of supply or return mains or distributing pipes, but the ducts should not be encroached upon by coil chambers constructed within them. Clear, unobstructed, smooth passages, with all angles rounded and all corners filled in, and all enlargements avoided, should present the least of resistance to the flow of air.

The foregoing formidable array of rules and data have been presented of necessity, for guidance in construction. They represent absolute and unalterable conditions in forced ventilation, and will enable any one to design, without mistake, when engaged in making original plans. It may be objected that the dimensions of ducts obtained by these rules are excessive, nearly to the point of impracticability, but in reply to this it must be stated that they (the dimensions) are less *by one-half* than can be employed for ventilating by heated currents alone (which is cold weather ventilation only), or for ventilating by exhaust shafts, heated in same way to induce currents (which is closed window ventilation). The frequent assertion of success of self-acting (as they are called) ventilating apparatus, often confutes itself, when the incompatibility of size of ducts is investigated.

As to the methods of distribution of currents from the branch ducts within a hall, and amongst an audience, the subject would call for longer discussion than there is room now to consider. It will only be said that at the mouth of discharge of each branch, baffling boxes must be arranged and provided, so that the afflux shall take place from an extended sur-

face, at a not greater velocity, within one foot of the surface, than two feet per second. A condition which calls for the area of surface to be ten times as great as the sectional area of the branches. And it is further required that the direction of afflux should be *upward* in general, or when horizontal it should meet some other current of afflux near by, and be directed upwards. The augmented current of afflux in horizontal directions, as in the risers of the seats or steps of an amphitheatre, is sure to engender local currents of much greater intensity than the original ones, and to become seriously objectional to an audience.

Whatever be the dimensions given to the supply ducts and passages, it must be remembered that those for removal of air must have adequate size, and if economy in the impelling force be studied, must be at least of equal dimension. In cold weather, with a high building—and all buildings are more or less high—the labor to be performed by any ventilating appliance in inducing a flow of air, is materially reduced by the ascensive force of the columns of hot air in the building. As the weather becomes warmer, more and more motive power is demanded to impel the current, but whatever motive power be expended, the movement of any quantity of air will cost in motive power as the square of the velocity. The supposition of any change in sectional areas (omitting some frictional considerations), which shall reduce them below the area accepted as the least at the fan, admits of a reduction of the fan itself to conform.

A thoroughly arranged ventilating apparatus calls for distributed removal of air as positively as it does for distributed supply, and for complete efficiency, all flues and branches of efflux should have, after providing the branches, similar baffling mouths to those described at mouth of entry, 1.4 times the area of the supply flues and branches.

With a forced ventilation, these flues should not have that compensation in reduced area, as they become high, which is essential to self-acting hot air shafts. The condition of ventilation assumed, supposes the expulsion of larger quantities of air, as the relative temperature inside and out, becomes more equal, and at the point of equality, the value of the height of the building as a shaft becomes nothing.

This large size of flues of efflux opens another source of trouble. It is almost indispensable that all the eduction flues shall be gathered into one single main flue, with judicious arrangement of the branches at their points of junction, so that they shall *direct* themselves into the general

current of effluent air, and entirely and completely fill the great flue or shaft, thus preventing any eddies or back currents from establishing themselves, from room to room, from one part of a room to another; or worse yet, from the outer air down one side of a main shaft and up the other. With numerous ventilating flues or chimneys to open fire-places in any one building, whether supplied with air by forced ventilation, or by any other ventilation, or if unsupplied with air altogether, but merely furnished with *ventilating flues*, or yet again, where numerous chimneys only exist, *the chance for a down draft* for some of them goes beyond the theory of chances, and becomes a certainty.

At all events, for a hall, the ventilating branches must be gathered into one general eduction shaft, while it may be possible for separate rooms to have separate, independent ventilating flues, with a little possibility of most of them working the right way, if the weather is not very cold.

A few figures of the proportions of steam heating apparatus, in combination with ventilating, may be given. In most buildings to be ventilated, as halls, there will be found rooms and passages, whose requirements in occupancy will demand a much less liberal supply of air than the halls, or session rooms themselves.

The quantity of air supply to such buildings will be derived from two systems, whilst additional heating capability will be required from a third system. The system dependent upon ventilation of session, audience or largely occupied rooms, has been discussed already, but the least quantity for occasionally occupied rooms is much in excess of what is needed, where the heated air is made merely the vehicle for transporting heat to a room to be warmed. The temperature of currents for ventilation solely, can scarcely exceed 70 to 80 degrees in the coldest weather in the most exposed hall, while rooms warmed more economically with smaller quantities of air, may have hot air currents of perhaps 110 degrees from steam heated surfaces. In the second case, the volume of air requisite will be found by deciding on the extent of heating surface for a given room of given exposure of outer wall, and position in the building. This extent of heating surface may vary from 1 square foot to 40 cubic feet of space in the room, to 1 square foot to 120 cubic feet of space in the room. The latter value representing a room of ordinary living size, with the least usual wall or window surface, sheltered from cold winds, and in the second story of a warmed building; while the former value is that of the exceptional case of great exposure, or of

situation on the ground floor of the building. When an allowance for these circumstances has been made, and the quantity of heating surface needed for heating any room by indirect heating (as it is termed), has been reached, it may be accepted that 3 cubic feet of air per minute must be given to each square foot of heating surface, as the greatest quantity when the thermometer is at zero, at such time as the least supply for ventilation is supposed. A square foot of steam heating surface, with steam at 30 to 40 pounds pressure may be taken, *if well exposed*, to be capable of heating 3 cubic feet of air from zero to 100 degrees, or 5 cubic feet of air from 50 degrees to 70 degrees (or 80 degrees) in a minute.

It will be noticed that the heating capabilities of surfaces is referred to the cubic space in the building. The great loss or transfer of heat in any building takes place at the windows, so great that the computation might almost be confined to their surface as a unit to estimate on, and the surface of the walls or the cubic contents of the rooms be neglected. But, on the other hand, it is the *exposure* of the window which becomes of most account, and that has to be allowed for by judgment, and not by estimate, and with *exposure* a wall may become, if thin or thick, a material element in consideration.

Finally, the windows do bear a definite proportion to cubic space, or, if they do not bear the usual proportion, they may be *allowed* for ; until the skill in guessing comes back to a guess based on cubic contents, as equally valid with one based on window surface.

The third system of steam heating which finds examples in all large buildings—in passages, at or near doorways, or invariably somewhere—is direct heating by coils placed in the rooms to be heated. For this method there is demanded 1 square foot of heating surface for each 80 cubic feet of space within the walls of an exposed room, or of a room where the heating is demanded at short notice; as in an office which is allowed to become cold at night. While 1 square foot of direct heating surface is ample to warm 200 cubic feet of space continuously, without intermission day or night. Special demands to heat doorways and open passages, must be estimated on special grounds.

For heating in chambers with indirect heating (ventilation) box coils, as they are denominated, are best, while for office heating, vertical coils are decidedly preferable, although their surface is not so effective as that of horizontal pipe coils by about 20 per cent.

The main pipes for steam and return connections, by branch or direct

mains to each cluster, coil or radiator, should have the equivalent of 1 circular inch of sectional area for steam (or flow) connections (equal to 1 inch steam pipe nearly) for every 500 square feet of effective steam surface, augmented or enlarged 0.0025 ($\frac{1}{400}$) times for each foot from the point of first distribution or branch from the main. The condense water or return connection will follow the same rule, with the equivalent of ½ a circular inch for the same surface (equal to a ¾-inch pipe nearly). The aggregated area of great mains need not be so large as would follow from aggregating the branches, but should be increased in size up to the point of any branch, as if the enlargement of that branch, for distance, occurred at the point of branching, and not at the coil or heating surface. This rule will, if carefully read, prove easy to apply.

Flow mains should rise to some point (where they can be trapped or drained), vertically, and then have a descent of a ½-inch in 10 feet, regularly, to the end. If circumstances do not allow this, steps of vertical rises, well trapped, should be succeeded by lines of descending grade. The return main should have a corresponding fall towards the boiler, or other condense water recipient.

Boilers of the common tubular form require about 1 square foot of boiler surface (reckoning all the surface, of whatever kind, exposed to the fire or to the gases of combustion, between the grate and the boiler chimney), to each 9 square feet of heating surface in coils or radiators.

The grates of such boilers should have 1 square foot of surface to about 30 square feet of boiler heating surface. These ratios give 1 square foot of grate to 270 of radiating surface.

The chimney flues for the boilers (the stack) demand a sectional area from one-tenth of the grate surface, for chimneys of 50 feet high, to one-twelfth of the grate surface for chimneys of 100 feet high. These last dimensions are smaller than customary, but sufficiently large if no further requirement will ever be put on the apparatus.

The maximum quantity of coal to be consumed on these grates will not exceed 8 pounds per square foot of grate per hour, while the average quantity will not be over 20 to 30 pounds of coal per square foot of grate in 24 hours for 6 months of a year. A fan delivering 20 000 to 40 000 cubic feet of air per minute, will demand from 20 to 60 lbs. of coal per hour to supply steam, as a rough estimate.

In planning boilers, it is usual to allow one extra boiler for contingencies. There is no necessity to estimate on the supply of steam for

the power needed to impel the fan, where buildings are warmed and ventilated, as the exhaust steam of the engine should be utilized for heating purposes, and little extra steam is demanded for this purpose of driving the fan, so little, that the quantity may be neglected in the total of allowances for successful warming.

Further discussion might be had into the mechanical details, constructively, or as to either their ratios to the great units of individuals to be supplied with air for ventilation, or of cubic space in buildings ; of some possible interest to the construction of apparatus ; but my purpose has been only to give such figures and data as are indispensable for arranging the ventilation of halls of audience. Every word of superfluous description, and each extra figure, has been carefully eliminated, with the sole view of making this information complete in its ostensible direction. The paper, however, cannot properly be concluded except by calling attention to some requirements, that seem not to have heretofore been adverted to by other writers, but which really control the working of any apparatus, for either warming or ventilating, or both, and which call for modifications in arrangement and construction, almost amounting to a novel system.

The temperature of steam heated surfaces, for steam of such pressure, as is usually carried in heating apparatuses, where the boilers furnish steam for running the fan engine, that is, at 40 to 60 pounds pressure, will run from 290 degrees to 310 degrees; and these temperatures are practically uncontrollable whenever the steam is admitted to any coil or radiator ; so that the external surface of the coil or radiator in air is sensibly the same, 290 degrees to 310 degrees. Some slight but unreliable reduction of temperature in the steam, may be had by throttling the supply pipe, but this method becomes especially unreliable when the condense water is returned, without trapping, at the same pressure, to the boiler. Coils give off heat determinately until the last moment of being shut off. They fill with water, and become very noisy with water hammers; when a small volume of steam in someway is interposed between two columns of cooled water that instantaneously condenses it and forms a vacuum, bringing such columns into solid contact with each other. In exposed places throttled coils freeze up. The nicest adjustment may secure the end of lower temperatures of surfaces, and corresponding lower temperatures of air currents passing them ; or of desired constant temperature of air current, obtained by giving less heat to a warmer en-

tering air; but the least change of boiler pressure disturbs it all; in a moment the coil is virulently active with heat, or obstinately passive by water clogging.

There are two methods of meeting this difficulty. The first is the division of a coil into sections, so that one or more of the sections can be employed in heating or be shut off at will.* Some person in control of the apparatus, or at least of the coil for heating, will thus have the means at his disposal to produce any wished for temperature, down to the temperature of the outer air. The second method is found in passing around the coil, unwarmed, such part of the current of entering air as will reduce or temper down that remainder of the current which is permitted to pass through the coil, and is heated by contact with the heated surfaces. A comparatively simple arrangement of the casing of the coil, with register or louvre (blind) valves, and some baffling contrivance to secure the admixture of the two currents, is the mechanism of this method, which, as a method, is nearly as efficient as the former one.† In one essential regard it is more efficient, that is, the by-passing method gives an instantaneous change of temperature of the air delivered in the rooms, while the sectional method calls for time to elapse until the closed-off sections shall have lost their heat, or the newly opened ones increased in temperature, before any effect is produced on the temperature of the air.

It now becomes proper to remark upon the great general cause of failure of the well planned, thoroughly constructed, and entirely controllable apparatuses for heating and ventilating. Anomalous or paradoxical as it may sound, it is a fact, that the most complete apparatus may be the *most* perfect failure. Every improvement in mechanism may have been schemed, every contingency of working may be adequately provided against, and yet the accomplishment, in warming and ventilation, will have resulted disastrously. The fact is certain, and to what fundimental error can it be ascribed ? The mistake can, in my mind, be traced to the assumption, upon which the operating of apparatuses have been universally based, *of control* of the individuals warmed or ventilated,

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* In the heating apparatus constructed at the U. S. Capital in 1855-6, this method was introduced by Mr. Nason, and the complete control of temperature, in cold weather, for any given supply of air in every room in the building, was given to the engineer or his assistants.

† This arrangement, which was suggested by Mr. Faber du Faur, was introduced in one instance at the U. S. Capitol in 1858, and was entirely successful in the attainment of its purpose.

as regards their sensations of comfort, or their requirements for health. The error lies in giving the regulation of temperature to an engineer, or even to a general director (in case of an important building). An engineer may be a thoroughly competent mechanic, even more, he may be well informed in the practice, and possibly in the theory, of heating or ventilating. A director may have the theory and practice of heating and ventilating at his command, and be eminent in science or medicine as well, but from either of these, control will be resented, and any effort to enforce needful authority will be thwarted. If this be the condition of operating an apparatus in competent hands, what happens when those less likely to enforce authority are placed in charge? The usual engineer is a well taught mechanic, with ability to run and keep in order an engine, to direct the fireman, and possibly able to do his own steam fitting in repairs; one who in the pride he would take in a well kept apparatus, beyond the keeping of which he has no ambition, commands respect in his vocation. For such an engineer the capability cannot be expected which would allow him to direct or deviate when differing requests are made.

Any man may warm himself as he pleases. It is impossible for a number of men to tell one man what will please each of them individually, and for that one man to please them all. It is not the provision of means of control that will secure the wished for result. With every appliance failure is certain, unless those appliances pass into the hands of the persons to be warmed themselves. The neglect of this essential condition has led to repeated failures, until there is a popular belief that no ventilating apparatus can be successful, and there exists a general preference either for direct steam heating ; where an occupant of a room can manipulate the cocks or valves to his own liking, or for mere current warming; where opening or closing a register, also by any person in the room, controls the heat supply satisfactorily, when no importance is attached to the air thus adventitiously furnished or closed off. Only hospitals, or jails, or orphan asylums are happily ventilated, regardless of the volition of the sufferers, but greatly to the delight of ventilation doctors, whose experimental results are pleasant to contemplate.

While commenting thus freely upon the drawbacks of previous efforts, it is a suitable requirement upon the fault-finder that he should offer a remedy ; and a remedy will now be proposed, which is: That to the engineer, or persons in charge of the apparatus, should be delegated the

running of the same mechanically, in a defined way, without his or they assuming the regulation of the temperature of comfort in any room or hall; or part of a room or hall, where the magnitude of the same admits of division into parts. The temperatures desired or attained being positively controlled, within certain limits, by the occupants, or by representatives of the occupants, such as floor officials or ushers, in the rooms or halls. The limits of temperature proposed are 50 degrees for the lowest and 80 degrees (possible) for the highest. The supply of air at any one time should be constant and invariable, so that the equilibrium of distribution, will not be disordered by the closing-off or wide-opening of registers for admission of air—the usual process for controlling temperatures with heated currents at present.

The arrangement of apparatus to effect the foregoing, becomes necessarily a matter of original plan and construction, and is as follows: The boilers, fan engine and fan may be assumed, for convenience of running, as well as for better and simpler construction, to be placed in juxtaposition in vaults, at any desirable point about the buildings or grounds. Where the grounds near the building fall away, so that the boiler can be located above ground, and yet below the levels of the coils, this disposition of boiler is preferable. One of the advantages of the proposed method is, that except the cost of ducts and mains, the placing of boilers some distance from a building, say some 300 or 400 feet, is not objectionable.

When the desirable level for the boilers, with regard to the coils, for direct return of condense water without force, cannot be had, the return mains can descend to some separating recipient, where the condense water can be trapped-off to a hot well from which the boilers will be fed by a pump; or the coils may be trapped separately or in clusters, and their condense water taken by return mains to the hot well; or the coils may be trapped-off, and the hot condense water wasted; or yet, again, the return mains with regular descent may carry the condense water to a *closed hot well*, placed below the boiler level, under the boiler pressure, from which it will be elevated by a *closed pump* to supply the boiler.*

The main duct should be dry, air-tight, and closed as a passage way, absolutely without openings into rooms, vaults, or general passages, ex-

* This last very valuable improvement in the arrangement of return mains was proposed and introduced by Wm. E. Worthen, M. A. S. C. E., of New York. It presents the same advantages, as regards the "air difficulty," that is found in direct return to the boilers.

cepting only such doors as may be necessary to give access to the duct for the purposes of the apparatus. Every precaution should be taken to make the main duct *inconvenient* as a thoroughfare. This main duct, in the arrangement of apparatus here proposed, may be carried under ground or under floors, anywhere amongst the foundations or cellar walls of the building; only prescribing that it shall be well built in smooth finished masonry, without angles, dry, air-tight and closed. Ducts smaller than twelve square feet sectional area, may be built of thin galvanized iron, or may be built of wood (with narrow, 3-inch wide boards, tongued and grooved, mill planed both sides), and lined with light sheet tin, with soldered joints. The wood work of ducts need not be expensive, but it should be substantial. While small ducts or branches can be cheapest made of thin galvanized iron, in permanent structures, brick work ducts, with arched or slate covered roofs, of all sectional areas, branch ducts included, is the best construction. Coil chambers should be built in the manner and of similar materials described for ducts.

Returning to the arrangement of apparatus: There is to be constructed either directly in advance of the fan chamber or close behind it, connecting to the main duct, an *auxilliary coil chamber* to hold an auxilliary heating coil. This auxillary heating coil should be built in at least four separate sections, (with perhaps a larger number for an extensive apparatus); and this coil should, in its aggregate of surface, have enough to heat the entire volume of air required for winter ventilation from zero (or from the supposable lowest temperature of winter) to 50 degrees. Besides this sectional arrangement of the coil, it (the coil) should be so placed in the coil chamber, that the air can be passed or by-passed, through or around any one or other or all of the sections, under the regulation of sliding doors or of louvered blinds, so that not only complete but instantaneous control of the heat of the entering air can be had.

With the use of these means of control of the heat of the air entering the ducts, to meet every temperature of the external air, the duty of the engineer so far as relates to the *heat* in the building (for the most part) ceases. He will be required to see at all times, when the outside temperature ranges below the limit of 50 degrees, that the air passing into the main duct has a constant temperature of 50 degrees.

This temperature offers great advantages in the transmission of air

currents. It allows them to be carried under ground, in cellars, near foundations and under floorings, to any desirable distance, without loss or gain of heat in the transmission. It places all the local coils in the building on an equality in the demand upon them to supply hot or heated currents. It will be found that half the heating surface for the entire building will be demanded in this auxilliary coil, and that this surface will be peculiarly efficient, because of the great difference between the temperature of the coil surface and that of the effluent air from the coil. With the reduction of dimension of the local distributing coils, a corresponding reduction of dimension of flow-and return-mains will be permissible. And an advantage of the highest importance is yet to be stated ; all risk of freezing up the return mains or the lower pipes of the local coils (or occasionally an entire coil) is obviated, while nothing but positive neglect, could allow freezing to occur in one of the sections of the auxilliary coil.

The local distributing coils should, perhaps, be sectional, in not more than two sections for the larger coils, but it is questionable whether any division of these may be necessary, although the writer would advise it in construction. These coils should be in chambers arranged for the air to be passed or by-passed, through or around them, by the regulation of slides or valves *to be placed under the control of the occupants of the room or of the officers or ushers in a hall.* The means for regulation should be solely in the rooms or halls, themselves, and any gradation of temperature of entering air from 50 degrees to 80 degrees, should be instantaneously commanded, without, however, varying the quantity of air regularly supplied. If, with these provisions, by any accident or neglect the extreme of heat or of cold be allowed in the air supply for a short time, the effect will not be serious, for the instant restitution, to what the occupants of a room may deem their temperature of comfort, is feasible. The settlement of degrees of discomfort amongst the number occupying a room, will have to be effected by tolerance, much as the fresh air is got in a railway carriage, where there is no one to blame but the passenger when a window is opened or closed.

In halls it is manifestly proper that the floor should be separated in divisions, each having its own supply of air, so that the local regulation may meet, not only the small differences of local requirement which always occur, but also the differences of individual demand of equally general, and even more urgent occurrence. The galleries of halls have

not merely a small difference in requirement, but at all times they demand two or three or even more degrees *less* temperature for entering air than the floors. In some cases, as in the Senate Chamber or the Hall of Representatives at Washington, and generally in all legislative or council chambers, the galleries are occupied by a crowd of spectators clothed, in cold weather, in heavy outer garments, while the floors must be comfortable for the members, who are by no means crowded together, in usual indoor clothing. At evening sessions when gas lights are required, the increase of temperature therefrom will be found mainly in the galleries, and it then becomes essential to supply them with cooler air than the rest of the hall. It is a consequent necessity for the successful ventilation of halls, that the gallery supplies of air be distinct and separate from those to the floor; and it is much better to arrange for these supplies in separate divisions, one, if not two, to each side of the hall.

The duty of the engineer of the apparatus, so far as the local coils is concerned, will require him to put in use one or both sections of such coils to meet the demand of the season or day as regards mere warming and positive heating. Beyond this he has, whenever the external temperature is below 70 degrees, only to see that each coil is supplied with steam, and in satisfactory operation as a steam coil, under full boiler pressure. With this, and with his charge of the temperature derived or proceeding from the auxilliary coil, his responsibility for heating the building in cold weather ceases. As the weather becomes warmer in any year, and when the external temperature reaches 50 degrees, the auxilliary coil is thrown off. At 65 degrees to 70 degrees the local coils cease to be operative, and thereafter the engineer, running the fan at double rate when summer ventilation is required, supplies to such hall, (the ventilation of which was based on ten cubic feet of air per person per minute), the maximum of twenty cubic feet; which quantity will be found nearly all that can well be delivered amongst a crowd, where each person occupies, say four square feet of floor space, or the average theatre allowance.

Economy in running an apparatus, must always be considered in planning the same, and no building can be *ventilated* to the full extent continuously, whether its hall be occupied or not, with any proper regard for expenditure. It follows that notwithstanding what has been said about exonerating the engineer or director of the control of the heating,

there must yet be left, with these persons or one of them, the means of reducing the air supply to meet the real necessities of use or vacancy—of complete or partial occupancy. This may be effected in part by the running of the fan, but it will be found necessary to provide for regulation of air delivery by closure of ducts or branches to some extent. As the local coil surfaces are unalterable, the effect of employment of a greatly reduced volume of air at times, will be to enable them to give currents of much higher temperature than 80 degrees.

Thus in a hall with 1 200 people, at a minimum of 10 cubic feet per person per minute, we have 12 000 cubic feet per minute. If the local coils can take this air at 50 degrees and heat it to 68 degrees, which may be supposed to give 70 degrees in the room in moderate weather, and if the same local coils can take this air at 50 degrees and heat it to say 75 degrees in the coldest day (the 80 degrees heat from local coils is supposed in this case to warm up the room after it may have been chilled for want of heat), and also to give 70 degrees in the room ; it is evident that reducing the quantity of air to 1 200 cubic feet per minute, these same local coils are sufficient in extent to carry the 1 200 cubic feet from 50 degrees to over 125 degrees in the same minute of supply, and at this temperature the room will be warmed to 70 degrees against zero out of doors, at greatly less expenditure of fuel. For in one case there is wasted of vitiated air, 12 000 cubic feet which had been taken at zero and allowed to escape at 70 degrees, while in the other case, only 1 200 cubic feet, taken also at zero and escaping at 70 degrees, is demanded in effecting the heating.

This possiblity of economizing in the working of every system of ventilation is the bane of all methods. Ventilation is not economic as a process of warming. In many instances after a demonstration of successful ventilation, the working of the apparatus is permitted to degenerate to the barest warming. There is demanded a conscientious persistency in maintaining a thorough ventilation, where the warming can be made satisfactory without it, that surpasses the moral appreciation of a money-getting manager or of an economic official.

In presenting this optimist view of the subject of practical ventilation of halls of audiences, it must be accepted as indicating the path of advance, not as demonstrating the impropriety of advance. No expenditure is justifiable which cannot have the assertion of necessity, nothing surpassing the admitted wants of society will be appreciated or

willingly paid for. The current belief and faith in the necessity for purer air in halls, must be entertained by the audiences, before the expenditure for provision or of maintenance of ventilating apparatuses can be warranted. It is sure that people do become less tolerant to the closeness and odors of halls, court rooms, school houses, year by year. This is evidenced by the extravagant schemes of sanitation of such places on the one hand, and by the boasts of impossible accomplishment with wholly incompetent means on the other, that find so frequent publication. It has been the purpose of this paper to set forth the least quantity of air supply, compatible with relative purity in the air of an occupied hall, and then without gloss or extenuation, to set out the difficulties and costs in obtaining this least quantity, and the inconvenience and discomfort attendant, so that they shall all be appreciated as incident to the problem of ventilation.

Above all, in the effort to give or establish practical limits for the necessities of ventilation in halls of audiences, which can with safety be aspired to at this present time, and with justice be demanded by the community from all those who control the management of audience or session rooms, it is not wished to be misunderstood by supposing that this paper has been or is, advocating the dispensing with any real demand in quantity or quality of the supply of fresh, pure air. Compliance with the present *system of ventilation* of hot air furnaces, which *system* is merely heating to requisite intensity, with adventitious supply of air, is as far from the ideal of perfection, as the scheme of giving to the occupant of a hall, the healthful air of the mountains, with the freedom and volume of the west wind, is from the possibility of construction or of operation. Little by little modern society appreciates the conditions of healthful, civilized existence. The removal of cause of offense is the first requisite of sanitation, and it is the first requisite of ventilation. Our tolerance of personal uncleanness in small ways, and in large ones also, goes far to account for the offensiveness and unhealthiness of many places of public gathering. Arguments on this point, and social enforcements of regulations in this regard, in theatres, court rooms, galleries of public halls, school rooms, public conveyances of all kinds (especially the latter), will be more efficient than the indoctrinating of surmounting the difficulty by gales of fresh air, funished regardless of comfort and of expense.

Finally, after establishing the *requirements* for necessary and indispensable ventilation of audience halls and of audiences it becomes

the indispensible preliminary, that the original planning and subsequent erection of the buildings shall provide suitable rooms for apparatus, together with ducts, distributing passages and flues, in order to render available the methods of the mechanical engineer; by which methods ventilation, with comfortable heating, can now be effected with controllable, positive and satisfactory result.

Addenda.

FANS.

Data relating to fans for ventilation, to be used in preparation of plans of buildings.

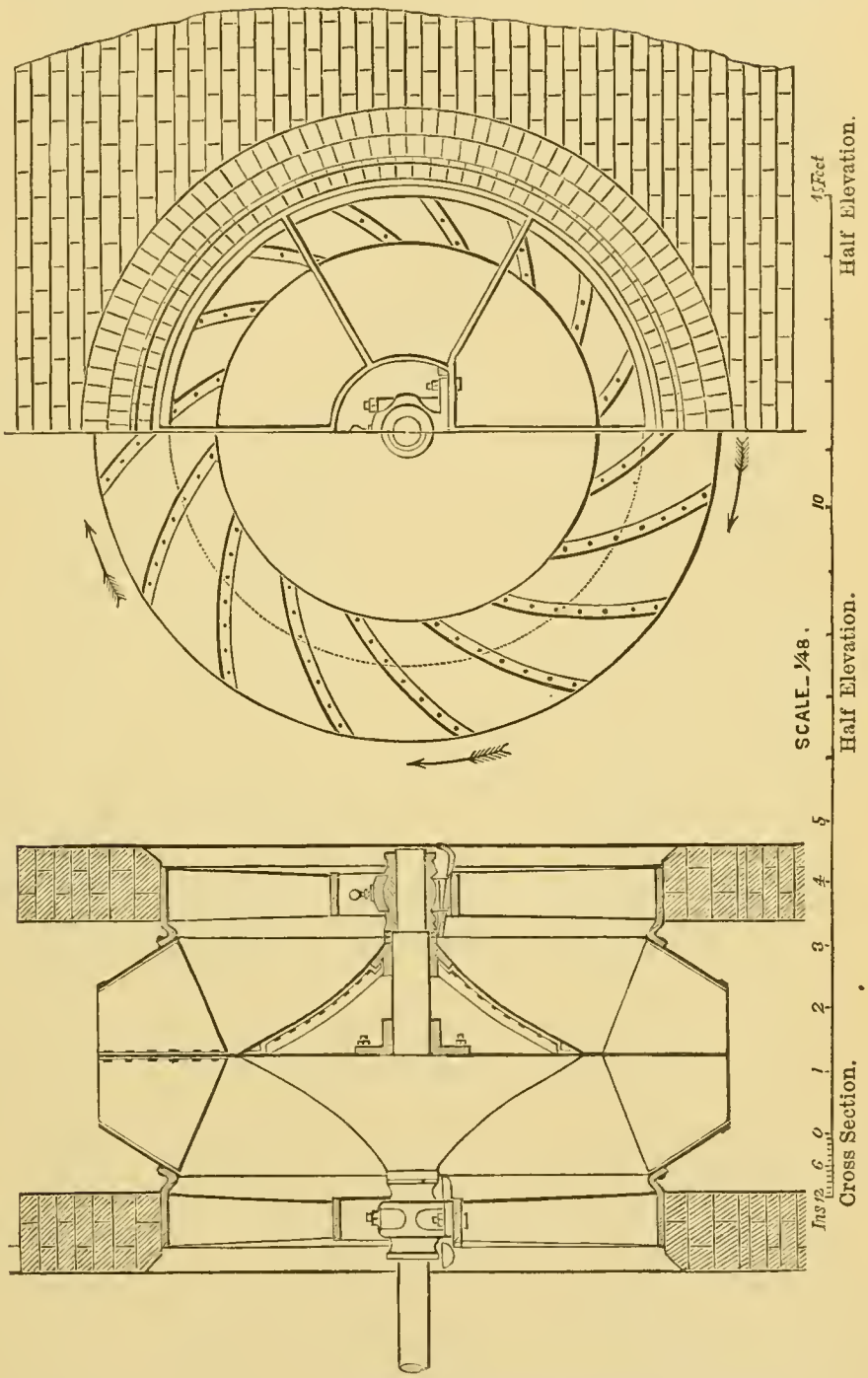
The following illustrations, together with a table of practical data, have been taken from the paper, "On the conditions and the limits which govern the proportions of Rotary Fans," read before the Institution of Civil Engineers, London, in 1870. This paper was offered to the Institution by the present writer. As before stated, this fan construction offers the advantage of giving the least possible dimensions for the performance of a given work, in the movement of air. To some the sizes of parts of the fan, or of the air ducts, may seem large; but when the quantity of air is fixed, the economy of power demands low velocities and pressures in the ducts, so that large ducts and large fan mouths become necessities.

The sections and elevations, Fig. 1 and Fig. 2, show a double fan, that is one receiving air at both sides, through openings in partition walls, and delivering it at the periphery, into the space enclosed by the partition wall, from which space the air passes to, or enters the duct. The arrangement and construction of a single fan supposes a *half section* on the line of the disc, to represent a complete section of the single fan. These views show a sheet-iron ring, a piece of a cone attached to the mouth piece, as forming the sides of the fan. For single fans it is not unusual to form this side in a splayed ring of brick work. The fan illustrated is, as the scale shows, of 10 feet diameter. The fan shaft, whether for single or double fans, should have two bearings immedietely near the fan, in each mouth, as shown in Fig. 1; or in case of a single fan, one bearing in the mouth, and the second, on a back pedestal behind the fan; and besides these there must be a third bearing, to which the shaft extends, near to the driving pulley or the crank, from which the fan receives its power. The shaft should be long enough to allow the pulley or the engine to be located in a room separated by a partition from the passage for air, in entering or passing from the fan. Damp air being destructive of belting, and an engine room in a gale of wind, and practically out of doors, being manifestly an unsuitable arrangement.

Figs. 3 and 4, give the constructive diagram for fans of the type suggested.

EXAMPLE OF GENERAL DIMENSIONS OF A FAN OF 10 FEET DIAMETER.

PLATE V.



Referring to Figs. 3 and 4 the dimensions in practice then become when R = unity

A	= radius of inlet	= 0.742
B	= width of inner edge of blade . . .	= 0.35
E	= " outer " " . . .	= 0.2
C	= " zone of blades on disc . . .	= 0.4
F	= " " " on case . . .	= 0.258

K	= face of curb in front of disc	= 0.373
L	= place of centre line of pedestal in front of disc .	= 0.5+0.08 ft.
D	= radius of shaft	= 0.046
G	= " hub	= 0.075
V	= " contour of cone	= 0.94
W	= locus for centre of V in front of disc . .	= 0.92
X	= " " " " from centre of fan . .	= 0.829
Y	= radius of loci of centres for generating curves for blades	= 0.844
Z	= radius of generating curve for blades, approximate 45° logarithmic spiral	= 1.194

PLATE VI.

Fig. 3.

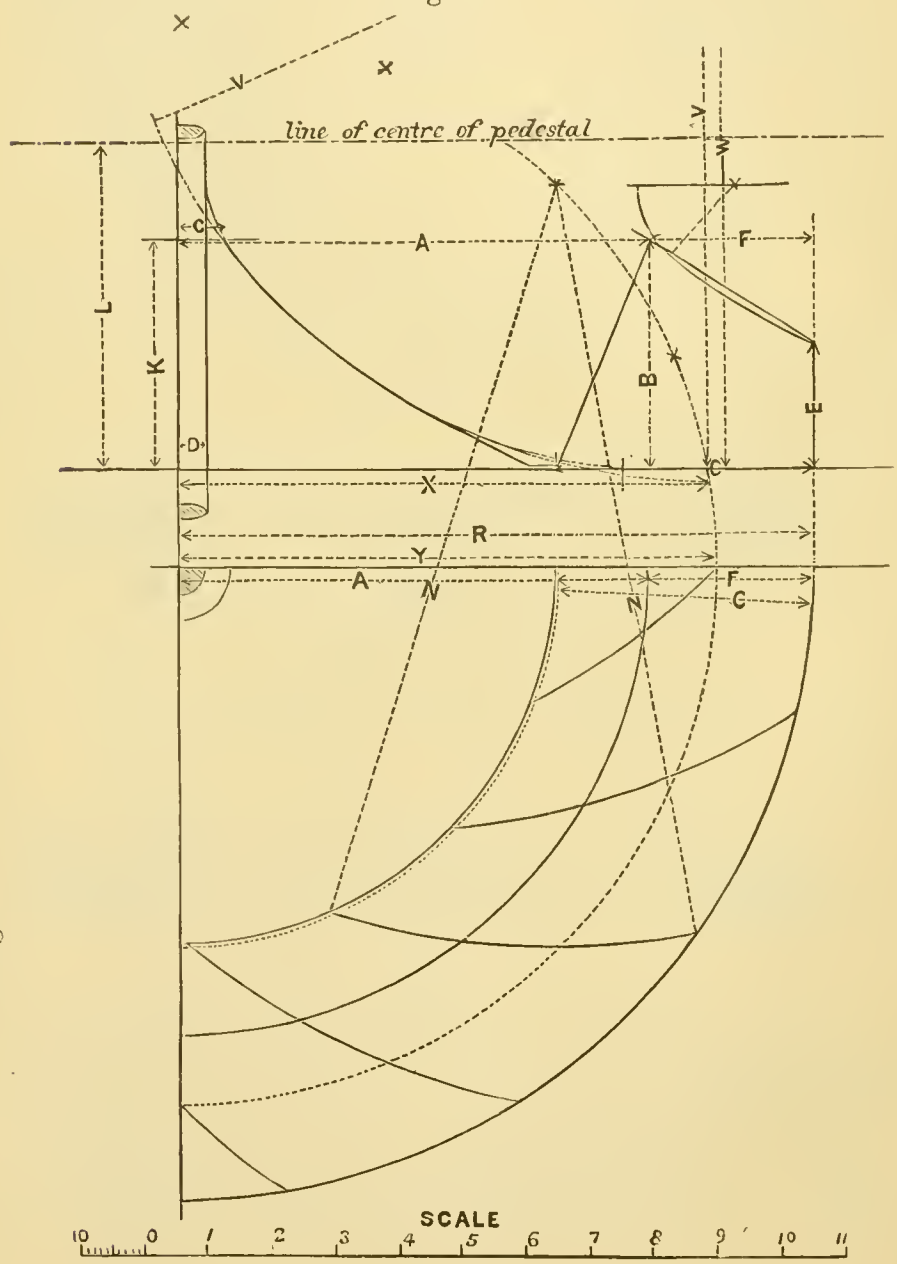


Fig. 4.

Fans to be Used in the Ventilation of Buildings.

Diameter of Fans.	Revolutions per Minute.	Quantity of Air delivered per Minute, corresponding to Number of Revolutions and Pressure.*	Pressure, difference between inlet and outlet of Fan, corresponding to Number of Revolutions taken.*	Horse Power required to deliver the quantity of Air at given pressure.	Dimensions of Pulleys.**			Proper Sectional Area of Delivery Air Duct, or Passage.***
					Number of Pulleys.	Diameter of Pulleys.	Width of Belt demanded.	
Ft.	Number.	Cubic Feet.	Water Column In. dec.	H. P.	No.	Ft. In.	Ft. In.	Square Ft. dec.
16	$62\frac{1}{2}$ to 125	102 500 to 205 000	0.31 to 1.23	$7\frac{1}{2}$ to 59	2	8 4	1 2	160·8
14	70 " 140	80 000 " 160 000	" " "	$5\frac{3}{4}$ " 46	2	7 6	0 10	113·2
12	83 " 167	57 500 " 115 000	" " "	$4\frac{1}{8}$ " 33	2	6 9	0 8	90·5
10	100 " 200	40 000 " 80 000	" " "	$2\frac{7}{8}$ " 23	2	5 2	0 6	62·8
8	125 " 250	25 500 " 51 000	" " "	$1\frac{7}{8}$ " $14\frac{3}{4}$	1	4 0	0 8	40·2
7	140 " 280	20 000 " 40 000	" " "	$1\frac{1}{2}$ " $11\frac{1}{2}$	1	3 6	0 6	28·3
6	167 " 333	14 400 " 28 800	" " "	1 " $8\frac{1}{4}$	1	2 8	0 5	22·6
5	200 " 400	10 000 " 20 000	" " "	$\frac{3}{4}$ " $5\frac{3}{4}$	1	1 10	0 5	15·7
4	250 " 500	6 400 " 12 800	" " "	$\frac{1}{2}$ " $3\frac{3}{4}$	1	1 4	0 4	10·05

* Double the quantity of air will be delivered each minute if the resistance to discharge or suction is brought down to one-half the pressure given in the pressure column, and the pressures may be increased (the number of the revolutions of the fans remaining constant), by closing partly the inlet or outlet, the quantity of air delivered being gradually diminished until the inlet or outlet be entirely shut off, when the pressures will have risen to double those stated in the table.

** The dimensions of pulleys and belt refer to the largest capacity of the fans given in the Table, it being supposed that it may be desirable to range from the lowest quantity and pressure to the highest in each case.

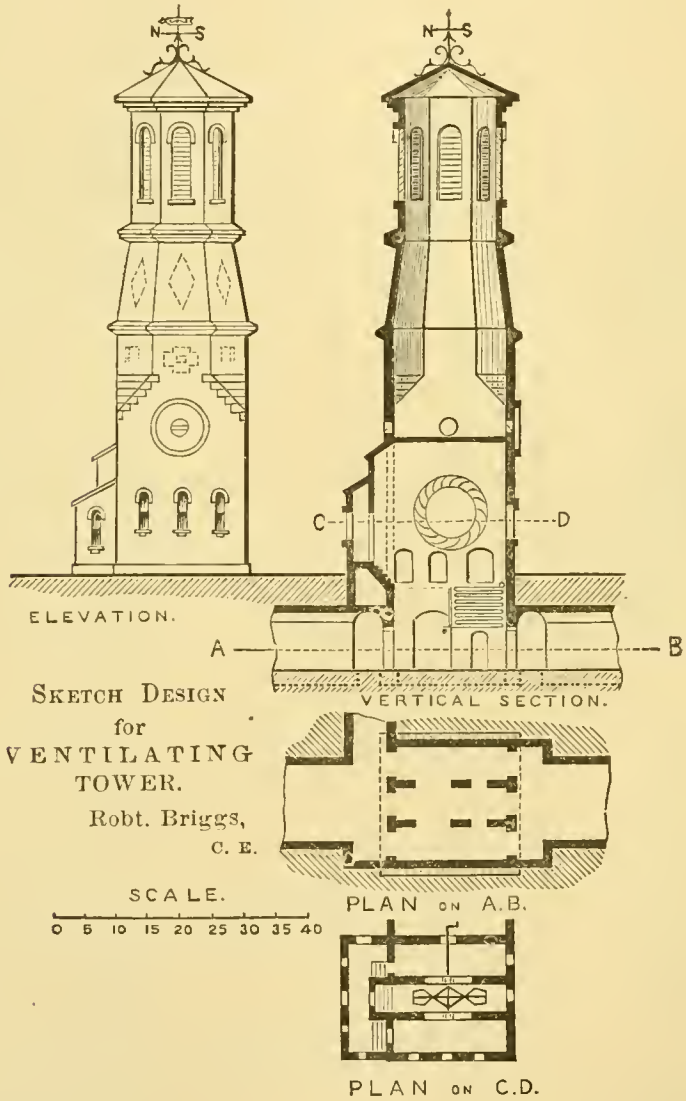
*** The sectional area of the inlet or suction air-duct or passage should exceed the area given by 1·4 time, to allow a fan to produce its fullest effect. It has been found, when it was inconvenient to make the air-ducts or channels of full sectional area to the end of a system of distribution, by enlarging them 0·0025 per foot of length, so that outlets and channels, at the distance of 400 feet, were provided with double sectional areas, that the falling off of pressure was satisfactorily compensated for, at the more distant outlet. It is obvious this rule will not apply to very small air-passages. When the relationship of quantity and pressure corresponds to that given in the Table, and it is never expected that a larger quantity will be required at a reduced pressure, the sectional area of the delivery air duct may be reduced one-half, or nearly to that extent. The sectional area given, admits the passsge of double the quantity of air at one-half the pressure. The frictional resistances of the sides of a duct are so considerable, that the largest duct possible should always be used, even when somewhat in excess of the dimensions given as those desired.

VENTILATING TOWERS.

§ The sketch design of Ventilating Tower, Fig. 5, is not offered upon architectural merits, but to exhibit an arrangement of ventilating tower, together with a fan, auxiliary coil chamber and auxiliary coil, and with underground ducts. The question of the source from which to derive the *fresh air* for ventilation of any building, is a very difficult one

PLATE VII.

Fig. 5.



to determine. The propriety or expediency of a tower at all, or if at all, under what circumstances, is not definitely settled. In one regard, that

§ This sketch is derived from a study for the ventilation of a public building made some three years since.

the tower is a monument to ventilation ! there is a strong architectural basis for its employment. Quoting in the main, from a discussion of a tower in a previous paper of the writer.* The dimensions of a tower are fixed by the quantity of air needed, and they will be found to be very large ones. To supply, for instance, from 20 000 to 40 000 cubic feet of air per minute, the sectional area of the air passage in tho tower, ought not to be less than 40 square feet. In other terms, the velocity of air in the air passage of the tower, should be not over 1 000 feet per minute.

How high must the tower be, so as to find pure air uncontaminated from *all* impurities, or so as to find that relatively pure air which shall meet acceptation ?

Investigation upon the purity of air in different places and at different elevations, and at different seasons, have been repeatedly made, the result of which, as regards cities may be stated with brevity. "There are great variations in the quality of air in different cities, arising from relative density of population, nature of fuel, character and avocations of the inhabitants ; and again, from climate, prevailing winds, and winds at the time of observation, hygrometric condition, normal or abnormal, etc., etc., but after the dispersion of impurity generated in any particular locality, the purest air is to be found from 6 to 40 feet, and the most impure, 70 to 90 feet above the level of the ground; with gradations from 90 feet high, rising to balloon height. Over any free or open places in a city, the dispersion of local impurities is more completely effected, and the uniformity of condition more generally obtained ; but the elevated air is more impure, when the stratum of diffused chimney exhalations is reached, than it is below. The haze of any large city is perceptible for miles on a still day—the entire city is covered as with a blanket by an ascending and dispersing cloud, and receiving its fresh air from beneath from all sides."

In the country, and probably amongst vegetation in the cities, as in parks or squares, the air near to the ground may be considered as the most humid, and the most likely to carry or propagate organic germs. In fact, it seems an instinctive requirement that causes all mankind to choose the second floor, or other upper floors of dwellings as the proper dormitory level. So that the argument appears to favor the taking of air for ventilation, both in cities and country, at some point from 6 to 40 feet above the ground surface.

* Rept. Vent. Hall Reps., 1876.

It may be remarked, that in large public buildings, where there is an enclosed court yard, not used by the travel of horses or animals, such yard is so repeatedly aerated by the removal of air for ventilation, as to become of itself a ventilating shaft, equal to any separate one that can be constructed. And it must also be noticed that the necessities of all buildings, as regards demand for fresh air, and their location or advantages in obtaining it, must determine the existence of a tower for air supply, as well as its dimensions. No tower is needed to obtain fresh air for the Mountain House at Mount Washington, not so much because of the elevation, as because of the local advantage of absence of sources of impurities.

ESTIMATION OF HEATING SURFACE.

The following gives an approximate estimation of the cubic space, in rooms or buildings, which can be warmed by a unit of steam-heated surface, placed in a chamber more or less remote from the room itself; the transmission of heat from the heating chamber to the room, being effected by currents of warmed air passing through flues.

The conditions upon which such an estimation is to be based are numerous, and it is here attempted to state them succinctly, if not briefly, as follows: The maximum temperature of the steam-heated surface is taken to be that derived from steam of 15 pounds pressure to the square inch, or 250° temperature of steam.* The surface employed is deemed equivalent in effective value for dispersal of heat, to that of plain cylindric surface in black, or unpainted, cast or wrought iron. Which surface may be considered to be typified by the ordinary "box coil" of one inch wrought iron pipe, not less than 10 pipes high, with air supply and delivery distributed by perforated plates, above and below the coil, into favorable contact with the pipe surface. Where other descriptions of radiating surfaces are employed precaution must be had to insure contact, as for instance, with plates or vertical tubular surfaces. While for plate surfaces having projecting ribs or pins, which may, in great measure, or entirely, answer the purpose of insuring favorable contact of the air with the surface, the efficiency of the superficies of the ribs or

* As was stated when discussing the uncontrollable temperature of steam heated surfaces, the common temperature of steam in large apparatuses runs up to 290° or 310° = 40 to 60 pounds pressure. 290° gives a surface over 30 per cent. more efficient to heat air from zero to 110°, than 250°.

pins may (where some considerable thickness exists, to give conductivity), be reckoned as half that of the plain surface to which they are attached.

It is also prescribed that the flues and ducts for the passage of the currents of heated air shall be of ample and *proper* size, as established in the text of this paper; and that they shall be well guarded from loss of heat, and metal lined throughout, to ensure smooth channel-ways, and all angles must be formed with gentle curves. These conditions especially refer to heating by self-acting currents, where the flow is produced mainly by the levity of the warm currents together with that of the warmed air in the room.

Qualified in these respects, it can be accepted, for the climate of Philadelphia, where the minimum temperature for any whole day of twenty-four hours is not below zero, that 100 cubic feet of space in the average of buildings used as asylums or hospitals, or 80 cubic feet of space for the average of buildings used for offices, will be adequately supplied with heat by currents of air of the proper volume, passing over one square foot of steam heated surface. In these buildings it may be assumed that the management of the apparatus is in the hands of a competent fireman, and that the boilers are run as is usual for those of factories. For dwelling houses where slow and irregular firing is the practice, the ratio of space to heating surface becomes about 60 to 1.

This ratio of 100 cubic feet of space to 1 square foot of heating surface is stated to be an average one for an entire hospital, and must be apportioned to the several rooms, with corrections for exposure of wall or window surface to the external air; that is, with regard to the points of the compass to which the frontages refer; with corrections for the proportion of window surface exposed; with corrections for unusual height of stories; with corrections for unusual thickness of wall, or for peculiarities in construction or methods of prevention of loss of heat at the windows; and in the case of self-acting apparatuses or those without a forced ventilation, with allowances for the elevation of the rooms in the building. In fact this last allowance may be made in any case.

It will be first attempted to set forth a simple rule for the apportionment of heating surface. It is thought that the second floor or story of a building will represent the average requirements fairly; when the first floor will demand, approximately, one-ninth more heating surface, and each story above the second may be held to require one-ninth less heat-

ing surface successively. Perhaps this rule would fail with the fourth story, where the elevation would be likely to increase the value of the external exposure as the occasion of loss of heat.

For the second or normal story, the number of cubic feet to be warmed by one square foot of heating surface becomes, for rooms facing as follows :

North =	80 cubic feet.	South =	120 cubic feet.
N. E. =	90 " "	S. W. =	110 " "
East =	115 " "	West =	85 " "
S. E. =	130 " "	N. W. =	70 " "

Average space per square foot of surface for the second story = 100 cubic feet.

The values for the several stories may be tabulated as follows :

TABLE.

Stories...	1st.	2d.	3d.	4th.	Stories..	1st.	2d.	3d.	4th.
	cu. ft.	cu. ft.	cu. ft.	cu. ft.		cu. ft.	cu. ft.	cu. ft..	cu. ft.
North ...	72	80	88	96	South ...	108	120	132	144
N. E.....	90	90	99	108	S. W....	100	110	121	132
South....	104	115	126	138	West	76	85	94	102
S. E....	117	130	143	156	N. W....	63	70	77	84

An approximate correction for extent of window surface may be suggested. A square foot of window surface may be taken as belonging to each 100 cubic feet of contents, of a room.

Having ascertained the excess or want of this extent of window surface in any room, one-half *the ratio* in excess or wanting to the (assumed) proper quantity may be taken as the dimunition or increment of the total cubic space for a unit of surface.

The other corrections suggested must be made a matter of judgment on the part of the person making the estimates.

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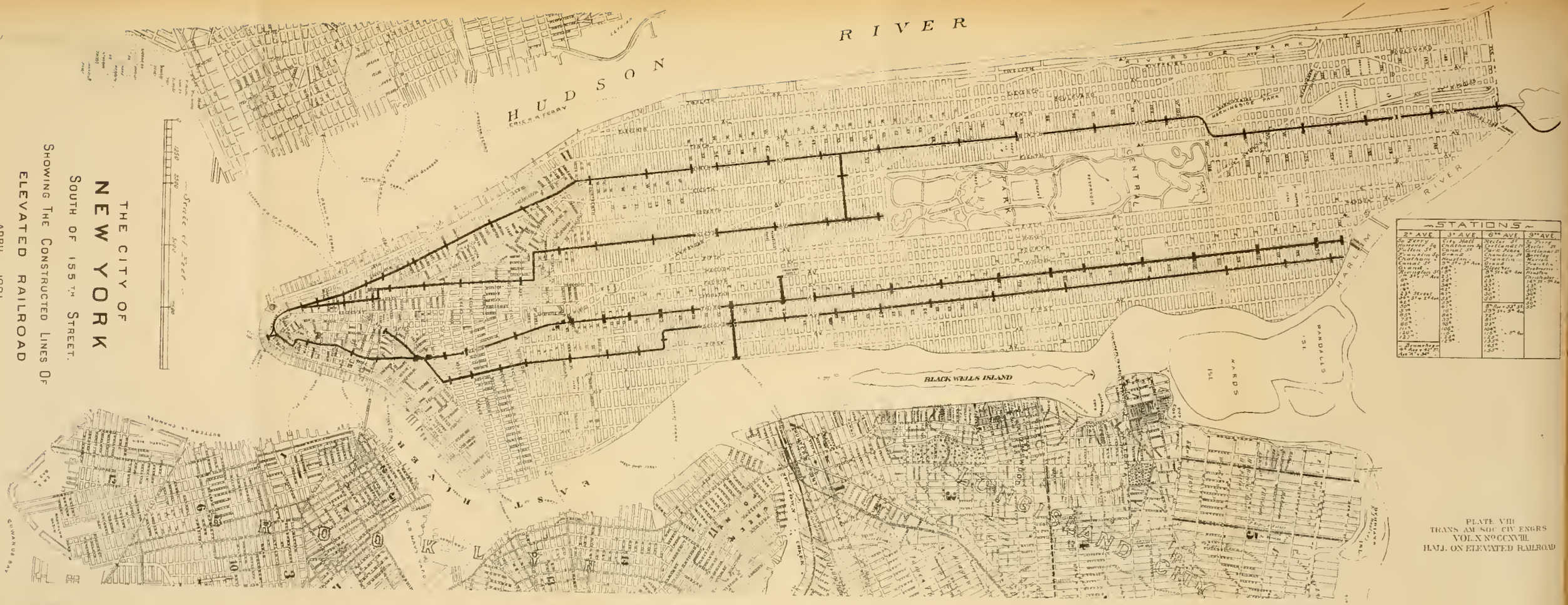


PLATE VIII
TRANS AM SOC CIV ENGRS
VOL X No CCXVIII
HALL ON ELEVATED RAILROAD

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXVIII.

(Vol. X.—April, 1881.)

ON THE CONSTRUCTION OF THE SECOND AVENUE LINE OF THE METROPOLITAN ELEVATED RAILWAY OF NEW YORK.

By G. THOMAS HALL, Member A. S. C. E.

READ APRIL 20TH, 1881.

In presenting a paper upon the Construction of the Second Avenue Line of the Metropolitan Elevated Railway in New York, of which Mr. Wm. F. Shunk is Chief Engineer, the writer, who has been the Division Engineer in charge of the work, feels impelled to apologize to the Members of the Society for its length and the recitation of numerous details, not easily avoided, however, in a comprehensive treatment of the subject. It has been written in the midst of the busy daily duties of professional labor.

DESCRIPTION OF THE ROUTE.

The line departs from the joint structure of the Metropolitan Elevated Railway and the New York Elevated Railroad at Chatham square, by curves of 230 and 250 feet radii for the up and downtown tracks

respectively. Expressed metrically, with radii of 70.10 and 76.198 metres. The uptown track has 55° 30′ 45″ and the downtown track 36° 10′ 40″ curvature; thence through Division street by tangent, excepting the uptown track, which has a reverse curve of 8° 18′ total curvature and radius of 1 910 feet (582.157 m.), to form a parallel track; thence into Allen street by curves of 210 feet (64.007 m.), radii, with curvature of 63° 03′; thence through Allen street by tangent to Houston street; thence by curves of 1 910 feet (582.157 m.), radii and curvature of 7° 41′ into First avenue; thence by tangent through First avenue to Twenty-third street; thence with a curvature of 90° and radii respectively of 136 feet and 110 feet (41.452 and 33.527 m.), on the up and downtown tracks; thence by tangent through Twenty-third street to Second avenue, and into Second avenue by curves similar to those at First avenue and Twenty-third street, excepting that those of the up and downtown tracks of the former correspond respectively to those of the down and uptown tracks of the latter; thence by tangent through Second avenue to One Hundred and Twenty-ninth street or the Harlem river. (See Plate VIII.)

TABLE No. 1.

TABLE OF LENGTHS OF TANGENTS AND CURVES.

LOCATION.	EAST TRACK.		WEST TRACK	
	Feet.	Metres.	Feet	Metres.
Chatham square Curves	222.80	67.908	157.80	48.907
Division street Tangent	1 004.60	306.196	991.10	302.082
Allen street Curves	231.12	70.444	231.12	70.444
Allen street Tangent	3 206.67	977.375	3 209 61	978.271
Houston street Curves	256 10	78.058	256.10	78.058
First avenue Tangent	5 448.38	1 660.636	5 438.50	1 657.625
First avenue Curves	219.90	67.024	172.79	52.665
Twenty-third street Tangent	503.00	153.311	503.00	153.311
Second avenue Curves	172 79	52.665	219.90	67.024
Second avenue Tangent	27 942.00	8 516.566	27 939.00	8 515.651
Total lineal feet and metres	39 207.36	11 950.183	39 118.92	11 923.228
Equals miles and kilometres	7.42 miles	1.950 kil.m.	7.409 miles	11.923 kil.m.

The curves are but little more than two per cent. of the length of the whole line.

The successive steps in the construction of an Elevated Railway are not wholly different from those which occur in building on the surface, as will be seen by the following natural order to which we conformed, viz. :

1. Preliminary survey.
2. Location of "layout."
3. Construction of foundations.
4. Setting cast-iron bases for columns.
5. Erection of iron structure.
6. Track structure and track laying.
7. Painting.

PRELIMINARY SURVEY.

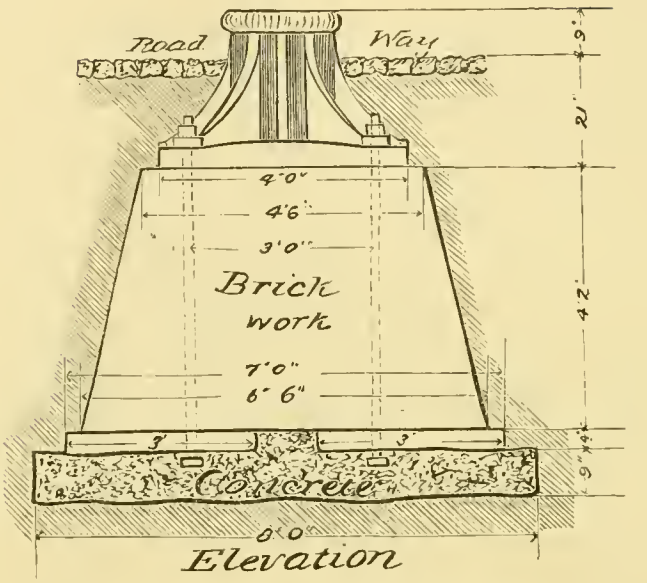
In order that no mistakes should be made in projecting a layout, or in the succeeding work of construction, this survey should be made, as it was, with the greatest care. The obstacles to the attainment of such a result in the crowded business streets of a city like New York are only known to Engineers whose patience and good nature have similarly been taxed quite up to the limit of elasticity.

It may be surprising to some to learn that no errors greater than one inch per one thousand feet (.0254 m. per 304.795 m.) of horizontal measurement, and five-thousandths of a foot per one foot (.0016 m. per .305 m.), in elevation were allowed.

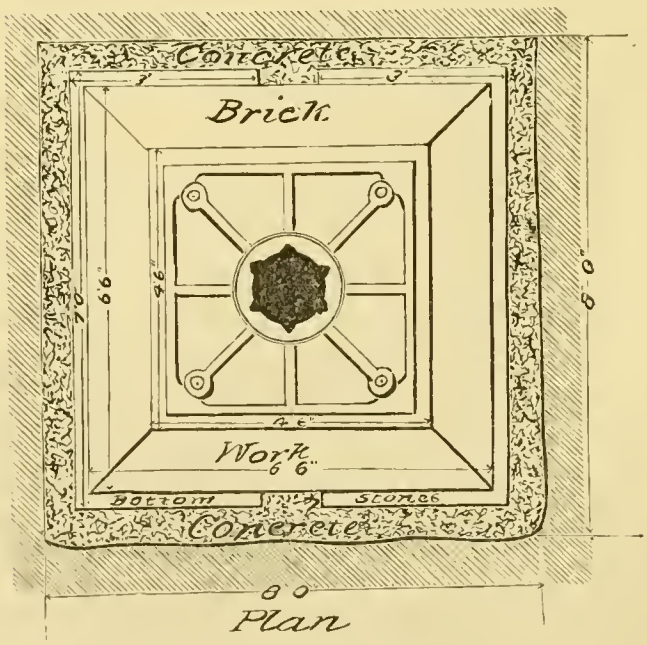
The first, and a very important step in the survey, was the adoption of a convenient base line that could be used until the final completion of the railway. It was located on the easterly sidewalks far enough from the curb line to escape any possible interference from the excavations for piers. No small difficulty was experienced in locating these base lines, especially on the avenues, where they are from one to five miles long, the requirements being a straight line parallel to the axis of the street or avenue. There is no angle in the First avenue base line, but to overcome several irregularities in the Second avenue line, and to prevent encroachment with our columns on the horse-car tracks, a few slight angles of a few seconds each were permitted on the base line ; these, where it was possible to do so, were located on summits of grades, and cannot be detected with the eye.

After permanently establishing the base lines, the longitudinal dist-

Standard Street Pier



Elevation

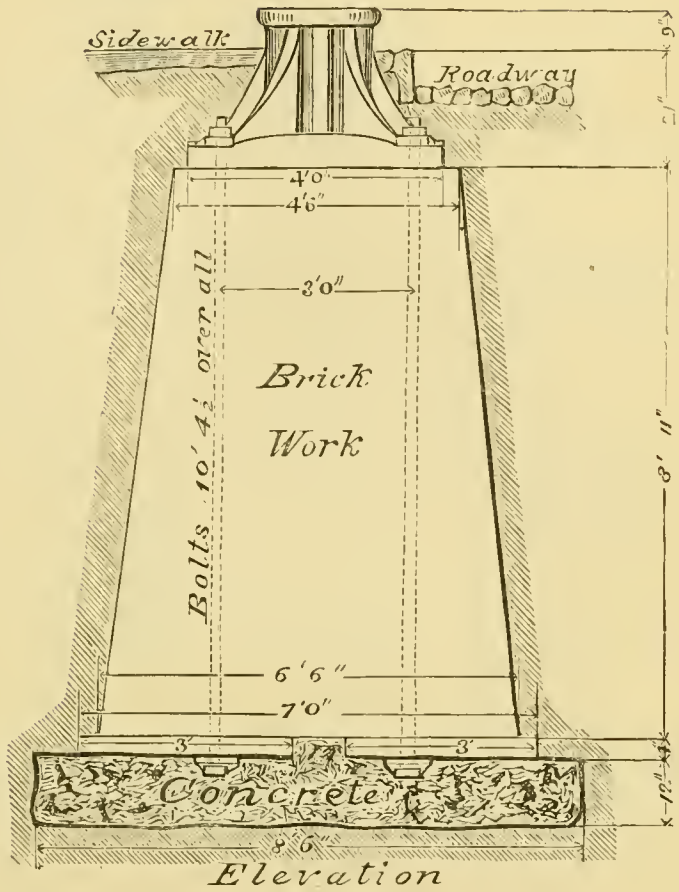


Plan

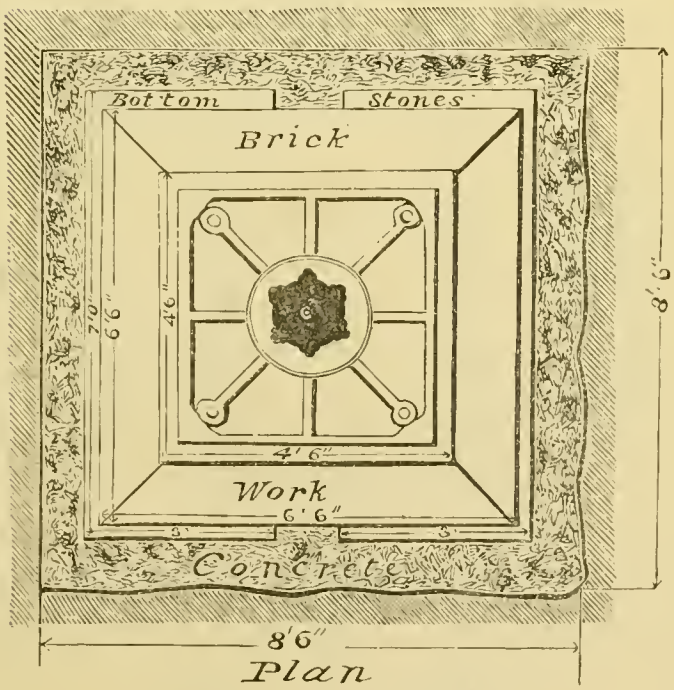
Scale { 1 inch · 4 feet

PLATE IX.

Standard Sidewalk Pier



Elevation



Plan

Scale { 1 inch = 4 feet
1 mm = 48 mm

PLATE X.

ance was measured with wooden rods 25 feet (7.619 m.) in length, the measurement being guided by a transit man. These rods were made by Young of Philadelphia, and pronounced by him to be accurate by the United States standard. Several auxiliary test standard lengths were first laid off at convenient points, where the rods were tested every morning for the day's measurement. Full stations were thus located and permanently marked every one hundred feet (30.479 m.) and sub-stations every twenty-five feet (7.619 m.) Following the measuring party was another small party, whose duty it was to locate all obstacles with steel tape from some of the full or sub-stations. It was found of the utmost importance in the subsequent projection of a layout that all such prominent features as sewer basins, fire hydrants, man-holes, lamp posts, telegraph poles, sewer, gas, and water mains, curb lines, house lines, vaults, chimneys, horse-car tracks, and large, important and public buildings, should be accurately measured and mapped. A location for the columns was then decided upon, and spotted upon the map for construction or verification. The spacing and arrangement of the columns on the street or sidewalk to support the structure is called the "layout." After the columns had been marked off at their proper sites, elevations thereat were taken for the purpose of establishing grade and determining the length of the columns.

For the purposes of construction, bench marks were permanently established every two blocks, or about five hundred feet (152.396 m.) apart. The profile of the Road is shown in Plate XXII.

CONSTRUCTION OF FOUNDATIONS.

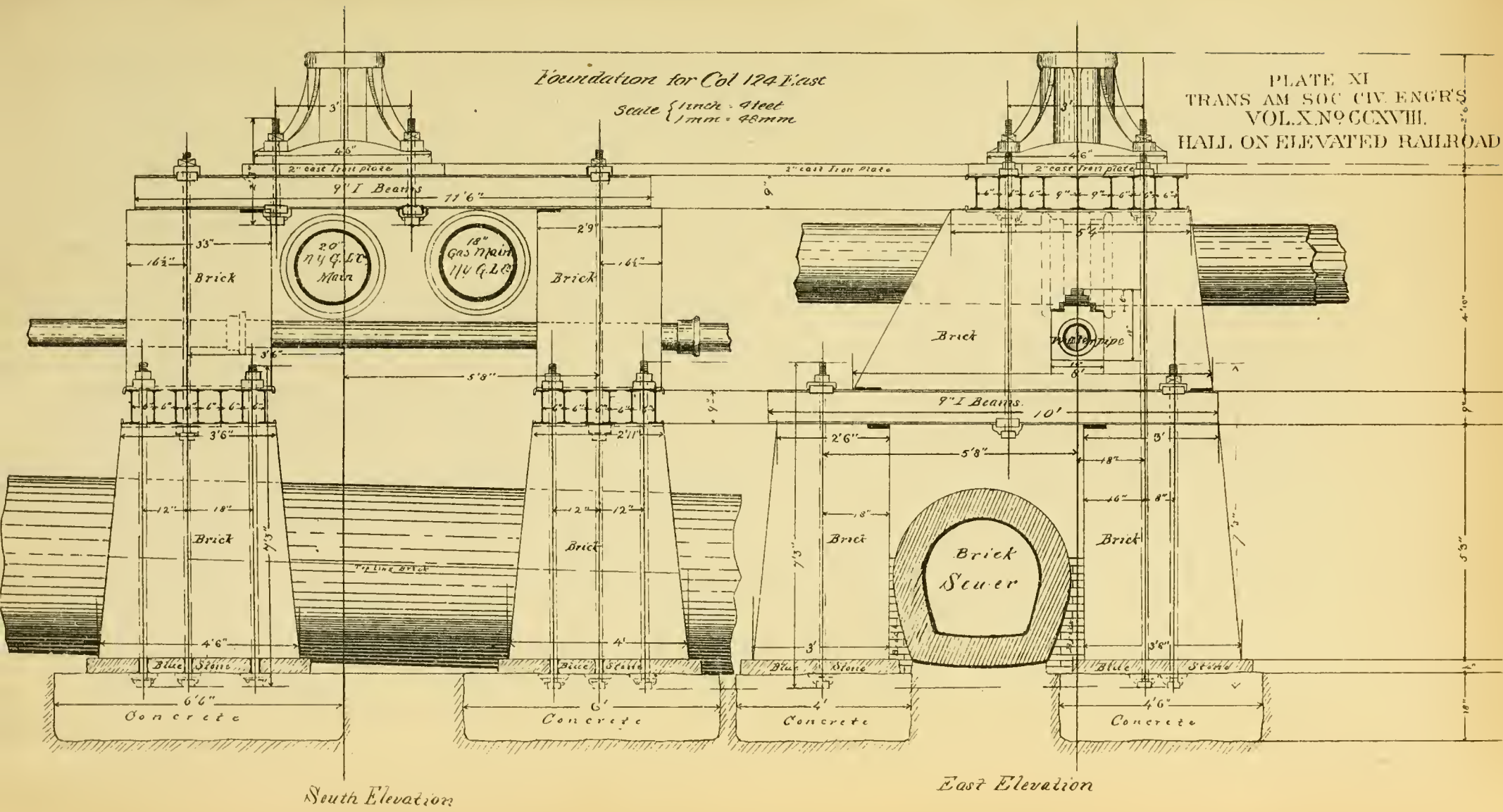
The requirements imposed by the Board of Commissioners of Rapid Transit in regard to foundations were :

1. The foundations, where necessary, shall be increased in area, so that in no case shall a weight greater than two thousand pounds to the square foot come upon any base (9765. kgs. per sq. m.)

2. Good hydraulic cement shall be used in the masonry, and Portland cement of the first quality shall be used in case the foundations are constructed of concrete. If bricks are used, they shall be hard burnt, and of the best quality.

No foundations were constructed of concrete ; all the other requirements were rigidly adhered to. Their classification was as follows :

1. Standard street piers.


Foundation for Col 124 East
Scale 1 inch = 4 feet
1 mm = 48 mm
PLATE XI
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2" cast Iron plate
9" I Beams
11'6"
20" N.Y. G.L.C. Main
18" Gas Main N.Y. G.L.C.
Brick
Water pipe
9" I Beams
10'
Brick Sewer
Blue Stone
Concrete
South Elevation
East Elevation

could not be built to the standard plan. The reasons for departing from the regular form of construction were foundations in quicksand, muck, made ground, or other soft bottom, adjacent or underlying water and gas mains, sewers, with their appendages of man holes, basins, culverts, &c.

Special Sidewalk Piers were those required when vaults or other subterranean obstacles were encountered.

The total number of piers built to date is 2 014—of which 1 496 are special. Of the latter number one hundred and ninety-eight rest on piles; the total number of piles driven was 3 310; the average length driven was 20 feet (6.1 m.) They were spruce, straight, straight-grained and smooth, free from large knots, divested of bark, not less than twelve inches (.305 m.) at the butt after sawing off, and eight inches (.201 m.) at the small end. They were driven to hard bottom, or until the set did not exceed one fourth of an inch (.0063 m.) under the blow of a ram weighing twelve hundred pounds (544.3 Kg.) falling eight feet (2.44 m.) The piles were hooped for driving, and sawed off horizontally one foot (.305 m.) below mean high tide level, their heads then being surrounded with concrete, the usual form of capping and flooring was used.

Elevations of four street piers and an isometric drawing of one are given in Plates XI., XII., XIII. and XIV., as fair samples of the prominent obstructions encountered on First and Second avenues. The frequency of the obstacles met with is made apparent by the fact that $74\frac{3}{10}$ per cent. of the piers are special.

The materials for concrete and hydraulic mortar were compounded by actual measure, and all cement was subject to inspection and test before use. The specifications for cement required it to be capable of resisting a tensile strain of fifty pounds to the square inch (3.52 Kg. per square cm.) after thirty minutes exposure in air and twenty-four hours immersion in water. The results of some tests made by the inspector of sand and cement are given in Exhibit 1, and show results from cement obtained from five different manufacturers. Much good sand was obtained from the excavations at different points along the work. The remainder was delivered on scows from "Cow Bay," Long Island, or "The Kill," on Staten Island. The latter, although much more difficult to obtain, was by far the better sand; both kinds, however, were required to be "bank sand."

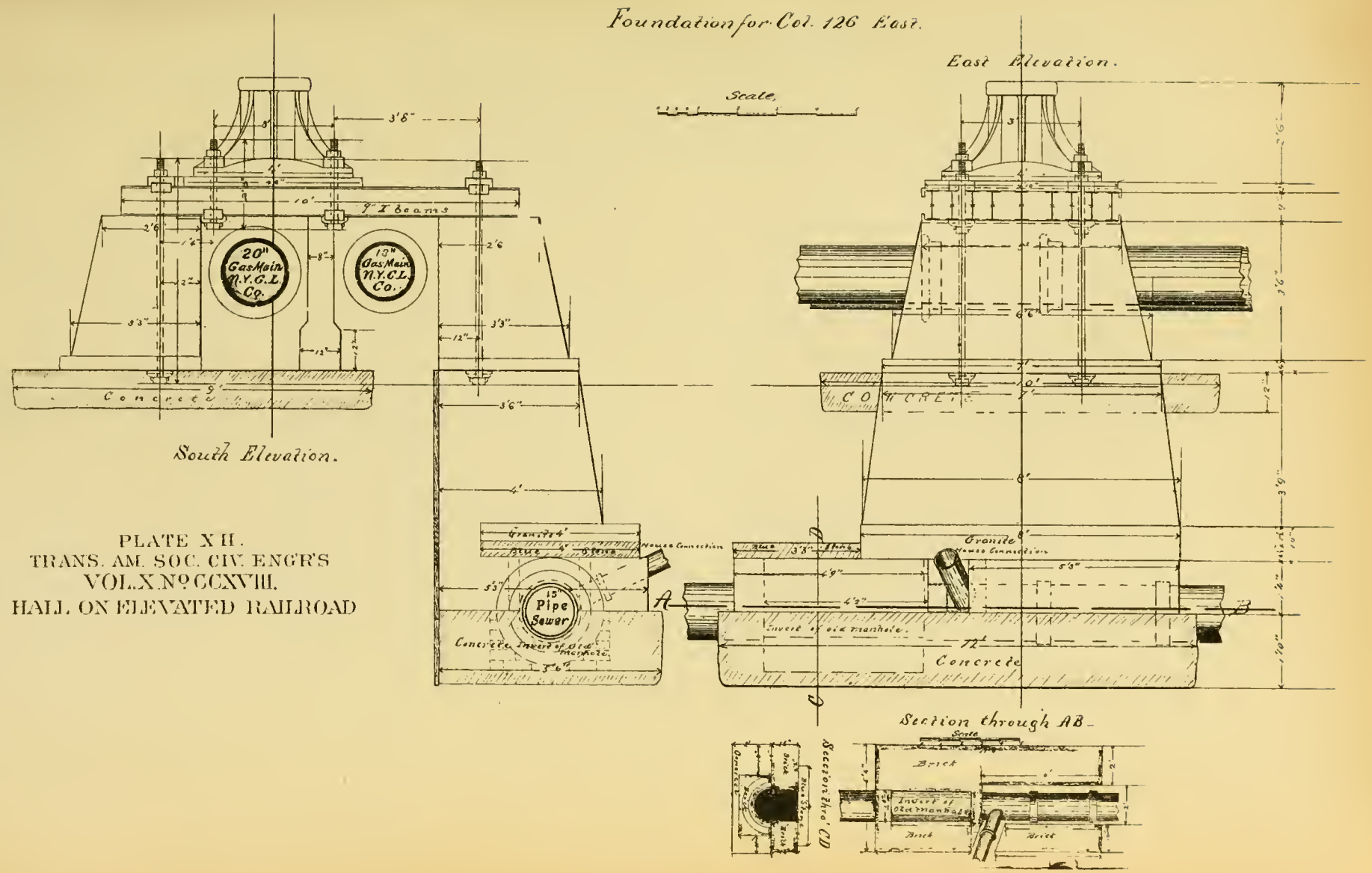

PLATE XII.
TRANS. AM. SOC. CIV. ENG'RS
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HALL ON ELEVATED RAILROAD

Exhibits of Tests of Rosendale Cement, used on Second Avenue Extension M. E. R.

Brand of Cement.	Proportion of Mixture : Time of Setting : Breakage per Square Inch.												Temperature.		Fineness.
	Neat.			Sand 1 ; Cement 1.			Sand 1½ : Cement 1.			Sand 2 : Cement 1.					
	Time.	Breakage. Lbs. per sq. in.	Breakage. Kg. per sq. c. m.	Time.	Breakage. Lbs. per sq. in.	Breakage. Kg. per sq. c. m.	Time.	Breakage. Lbs. per sq. in.	Breakage. Kg. per sq. c. m.	Time.	Breakage. Lbs. per sq. in.	Breakage. Kg. per sq. c. m.	Air.	Water	
F. O. Norton	24 hrs	44	3.09	24 hrs.	40	2.81	24 hrs.	40	2.81	48 hrs.	39	2.74	Avg. tem. 75° F.	68° F.	96:100
"	"	50	3.52												
"	"	42	2.95												
"	"	58	4.08	"	58	4.08	"	48	3 38	"	40	2.81			
"	"	50	3.52												
"	"	65	4.57	48 hrs.	60	4.22	48 hrs.	50	3.52	"	45	3.17			
"	7 days.	80	5.63	7 days.	60	4.22	7 days.	40	2.81	7 days.	40	2.81			
"	2 mths.	360	25.32	2 mths.	220	15.47	2 mths.	189	13.29	2 mths.	174	12.24			
"	5 "	560	39.38												
"	6 "	530	37.27												
Newark & Rosendale	24 hrs.	44	3.09										74° F.	70° F.	95:100
"	"	46	3.24	24 hrs.	40	2.81	7 days.	49	3.45						
"	48 hrs.	42	2.95												
"	24 hrs.	38	2.67	"	36	2.53	"	52	3.66	2 mths	114	8.02			
"	"	42	2.95	"	34	2.39									
"	"	45	3.17	"	32	2.25	1 mth.	175	12.31						
"	2 mths.	325	22.86	.....	.....	.....	.....	.....	.....	5 mths.	275	19.34			
New York Cement Company	24 hrs	42	2.95	24 hrs.	31	2.18	24 hrs.	36	2.53	.....	.....	.....	74°	70°	91:100
" "	48 hrs.	42	2.95												
" "	7 days.	62	4.36	.....	.....	.....	.....	.....	.....	.....	.....	.....	72°	68°	
" "	24 hrs.	48	3.38												
" "	"	48	3.38	48 hrs.	38	2.67									
" "	"	50	3.52	.....	.....	.....	24 hrs..	28	1.97	24 hrs.	30	2.11	71°	59°	
Hoffman & Lawrenceville	24 hrs.	48	3.38	.....	.....	.....	.....	.....	.....	24 hrs.	32	2.25	74°	70°	92:100
"	"	52	3.66												
"	"	42	2.95												
"	7 days.	68	4.78	.....	.....	.....	.....	.....	.....	7 days.	38	2.67	70°	67°	
Rocklock	24 hrs.	39	2.74												94:100
"	"	58	4.08												
"	"	62	4.36	.....	.....	.....	24 hrs..	38	2.67	7 days.	87	6.12	78°	70°	
"	"	47	3.31	.....	.....	.....	7 days.	94	6.61	.....	.....	.....	"	"	

These mixtures and most of the tests (except the long time tests) were made during May, June, July and August, 1879, from the cement as received from the mills. A much larger number of tests, however, were made. From accepted brands only a portion have been selected for this tabulation, which are probably sufficient to show the strength of the Rosendale cement used on short and long time tests for tensile strength.

Since writing the bulk of this paper the writer had occasion to build some twenty piers to connect the Metropolitan Elevated Railway on Eighth avenue with the Harlem River Bridge. As the cost of materials and labor have largely increased since the construction of the Second avenue line, an epitome of this work is shown in Appendix I.

It may be of interest to note some experiments made by the writer to ascertain the amount of shrinkage in the materials combined to make the hydraulic mortar used. The measurements of the sand, cement and water were carefully made in a box containing exactly one cubic foot (28.3 litres). It was found that in the mixture, including the water that was used, there was a total shrinkage of 37 and $38\frac{6}{10}$ per cent., respectively, for two different tests. Omitting the water in the deduction, it was found there was a shrinkage of $22\frac{1}{2}$ and 25 per cent. in the dry materials, after being mixed into mortar for use.

The following table shows the proportions used:

TABLE No. 2.

QUANTITIES IN CUBIC FEET.

Cement.	Sand.	Water.	Mixture.	Mortar Made.	Remarks.
4	8	$2\frac{3}{4}$	$14\frac{3}{4}$	$9\frac{3}{10}$	Experiment (1)
3	6	2	11	$6\frac{3}{4}$	" (2

QUANTITIES IN LITRES.

113.3	226.5	77.8	417.6	263.4	Experiment (1)
85.	169.9	56.6	311.5	191.1	" (2)

From these results it would appear that for any known quantity of cement mortar required, 25 per cent. of the amount should be added to the dry materials for shrinkage, the materials being used in the foregoing proportions.

PLATE XIII.
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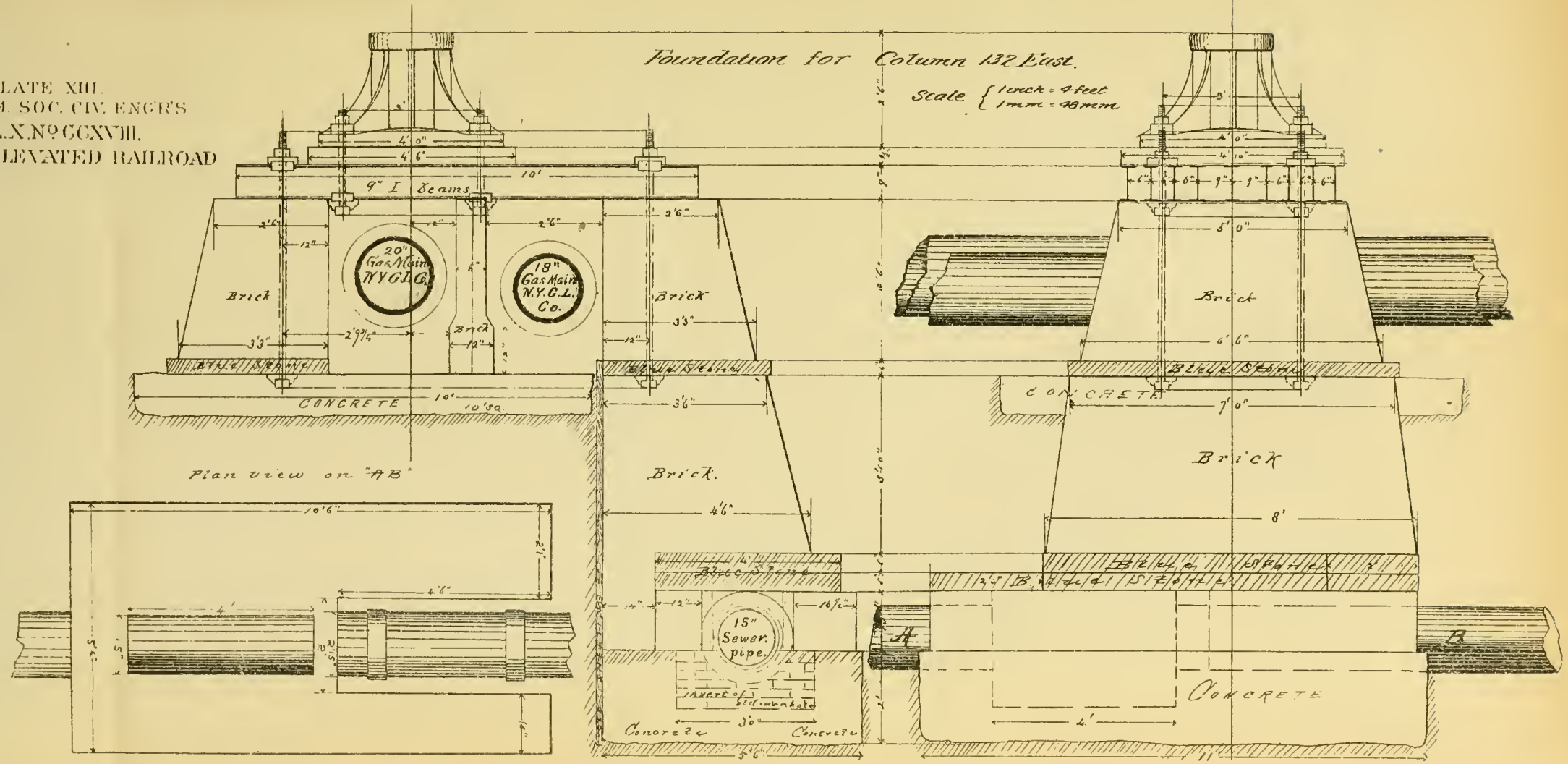


The total number of bricks used in foundations, including the station piers built to date (Feb. 1, 1881), is 14 841 198, or an average of 7 369 per pier. The Haverstraw brick, as laid in these foundations, numbered by actual count from 19 to 21 per cubic foot (0.671 brick per litre), the variation being probably due to the thickness of joint.

Cast Iron Base Castings.

There were six patterns of base castings, used and designated as follows: A, AD, AE, B, BD, and BE. The calibre of the first three patterns is 13½″ (.343 m.) for Phœnix columns, whose cross section area ranges from 36 to 39 square inches (232.3 to 251.6 sq. c. m.)

The calibre of the remaining three patterns is 13¾″ (.35 m.) for the same style of column, having a cross section area of 42 to 45 square inches (271 to 290 sq. c. m.) As the different patterns of the two calibres are essentially the same, only differing one fourth of an inch (.0063 m.) in diameter, sketches of three patterns only are shown in Plate XV.

The base castings were delivered by the company on the curb line opposite the piers where they were to be set. The proper elevation, together with the lateral and longitudinal adjustment of the base, was given by the engineer in charge, who also directed how the work should be done. The restoration of the street surface was made in all cases acceptable to the city street authorities.

The following tables show the actual cost of material and labor for setting the base castings by days' work, where the pier had been built and street restored before the base casting was set:

TABLE 3.

FOR A AND B BASE CASTINGS.

	TIME.	COST.
Time and cost of uncovering pier—2 men at 15c. per hour	1⅛	.35
" " moving base from sidewalk to pier—5 men at 15c. per hour	½	.40
" " erecting derrick and setting base casting—5 men at 15c. per hour	⅘	.60
" " repaving 25 square feet - 2 men at 25c.	1	.50
" " washing, tarring and bricking—2 men at 25c	⅔	.35
" " refilling—2 men at 15c	½	.15
" " preparing cement mortar—1 man at 20c.	½	.10

Foreman and night watchman	.50—2.95
Amount of cement used—¼ bbl. at $1	.25
" sand " —¼ bbl. at $1.25 per cubic yard	.05
Number of bricks used—32 at $10 per M	.32
Amount of refuse carted away—½ cubic yard	.38
" sand for paving 2½ cubic feet	.11
" coal tar, cement wash, &c	.10
Oil for lamps, and incidentals	.05—1.26
Total cost	$4.21

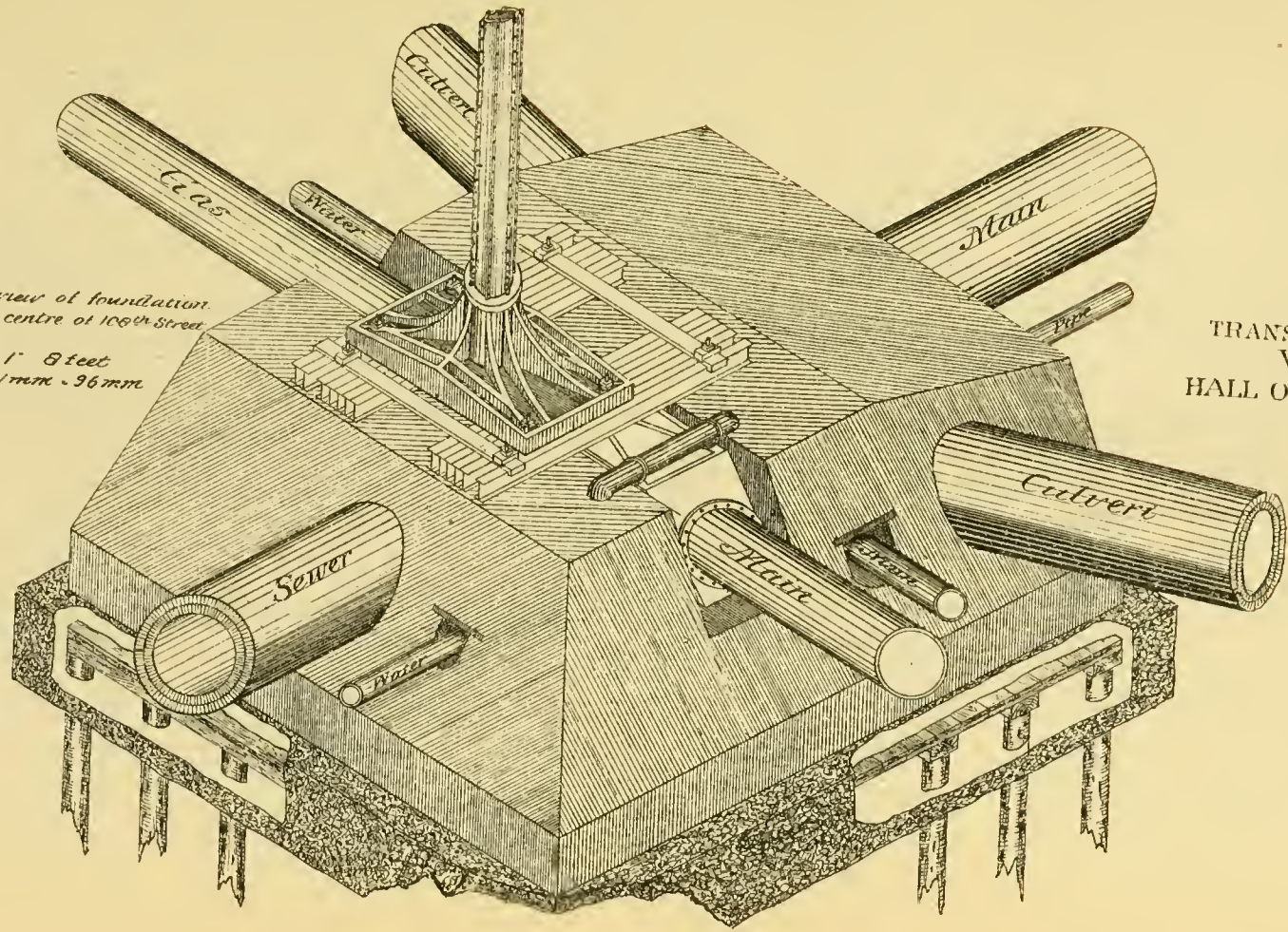
TABLE NO. 4.

FOR AD, AE, BD, AND BE BASE CASTINGS.

	TIME.	COST.	
Time and cost of uncovering pier—2 men at 15c. per hour	1¾	.50	
" " moving base from sidewalk to pier—5 men	¾	.60	
" " erecting derrick and setting base casting—5 men	1¼	.94	
" " repaving 40 square feet—2 men at 25c. per hour	1½	.75	
" " washing, tarring and bricking—2 men at 25c. per hour	1	.50	
" " refilling—2 men at 15c. per hour	¾	.23	
" " preparing cement—1 man at 20c. per hour	¾	.15	
Foreman and night watchman		.63—4.30	
Amount of cement used—½ bbl. at $1		.50	
" sand " —½ bbl		.10	
Number of bricks used—60 at $10 per M		.60	
Amount of refuse carted away—¾ cubic yard		.56	
" sand for paving 4 cubic feet		.18	
" coal tar, cement wash, &c		.15	
Oil for lamps, and incidentals		.05—2.14	
Total cost			$6.44

Where the base setting followed the construction of the brick piers, it was found that thirty-five per cent. of the above cost was saved.

The base castings north of Eighty-seventh street were set the year



Isometrical view of foundation for Col. 708 W. centre of 106th Street

Scale 1" 8 feet
" 1 mm = 96 mm

PLATE XIV.
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following the pier construction, and done by contract at the following prices:

For A and B base castings, including all labor and materials $3.75

For AD, AE, BD and BE base castings " " 5.25

A saving of about eleven per cent. on the former, and about eighteen per cent. on the latter style of bases.

The average number set per day by days' work or by the company was ten, while the average number set per day by contractor was fifteen. It might be well to state, in this connection, that the contractor gave his undivided, personal attention to the work.

The following table shows the average weight of the different kinds of bases used, number of each pattern, and total weight of all in tons of 2 240 pounds and 1 000 kilograms :

TABLE No. 5.

WEIGHTS OF CAST IRON BASES.

No. Used.	Pattern	Average Weight.		Total Weight.		
		Lbs.	Kgs.	Tons of 2 240 lbs.		Tons of 1 000 kilograms.
				T.	LBS	
1 463	A	3 204	1453.32	2 092	1 336	2126.21
49	A D	5 533	2509.75	121	0 420	122.98
50	A E	6 026	2733.37	134	0 840	136.67
409	B	3 205	1453.78	585	0 854	594.60
24	B D	5 510	2499.32	58	1 840	59.98
5	B E	6 048	2743.35	13	1 300	13.72
2 000				$3005\frac{94}{100}$ tons.		3054.16

The specifications for cast-iron column bases required them to be made of the best No. 2 Lehigh pig metal, or its equivalent in quality, three tons to one ton of machinery scrap.

The mixture was tested by taking a bar therefrom one inch (.0254 m.) square, and one foot (.305 m.) between supports, which was required to sustain at its middle point one gross ton (1016 kgs.), without fracture, the casting to be perfect in shape, the bolt-holes spaced exactly and cored square to the base. The cores for the barrels to be made

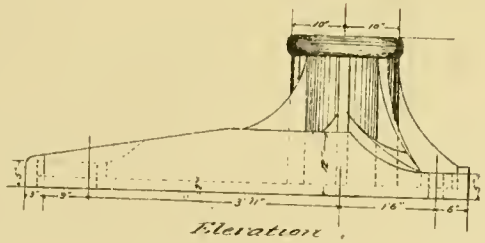
without draught, and blackened to get a smooth casting; great care was necessary in adjusting the barrels, and the spherical bearing at the bottom of the socket was cast chilled. The casting was then permitted to cool slowly, remaining in the sand not less than twenty-four hours. The bases described, by their peculiar form of construction, were difficult to cast. The distribution of the metal in the barrel, bottom of socket, ribs and flanges, while well calculated to resist the incumbent strains upon them, necessitates great care in founding. The iron, in cooling, shrinks along the ribs, while the expansion, owing to the large amount of metal in the centre of the base, still continues at the bottom of the socket.

These reactionary forces sometimes caused a bursting of the base. Other reasons, also, combined to produce similar results, such as the use of too hard iron, pouring while too hot, cooling the casting too quickly, or moulding in damp sand, the latter tending to ruin the core by expansion of air or steam, or both, and thereby rendering the bottom of the socket too thin for use. The bases were subjected to a rigid inspection by striking with a sledge, measuring the various parts and scrutinizing with a critic's eye before leaving the foundry. The final act of setting the base in position was also a good test of its perfect construction. Not a few were rejected in the last act. The bases were set to a given elevation—an elevation of top of base being previously determined for the whole line, chiefly dependent upon the grade of the streets. A bed of hydraulic mortar, from one-half to three-fourths of an inch (.0127 to .0191 m.), was given them that they might always be brought to a true elevation and to furnish a perfectly even bearing when screwed down to the brick pier. The ends of the bolts, together with the nuts, were then covered with a thick coat of coal-tar, and the whole base given a wash of pure cement mortar where the bases occur in the driveway. They were further protected by cast-iron bell-shaped fenders, which also prevent the wheel hubs of passing vehicles from striking the iron columns. The intervening space between the shell of the fender and the base casting was filled with cement mortar. Plate XVI. represents a fender in position, the base and column being shown by dotted lines.

Erection of Iron Structure.

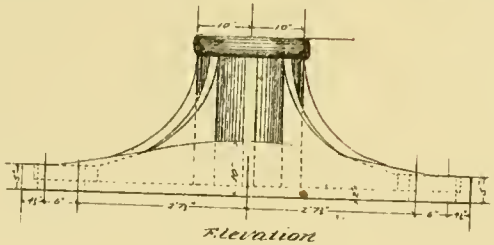
The iron structure is composed of Warren longitudinal girders of the deck system, whose upper chords rest upon the top chords of transverse

Patterns of Bases used on 2nd Ave. Line



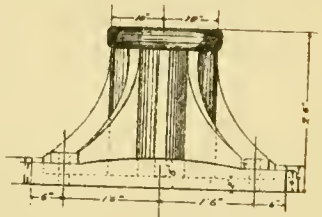
Elevation

AD, or BD, Pattern



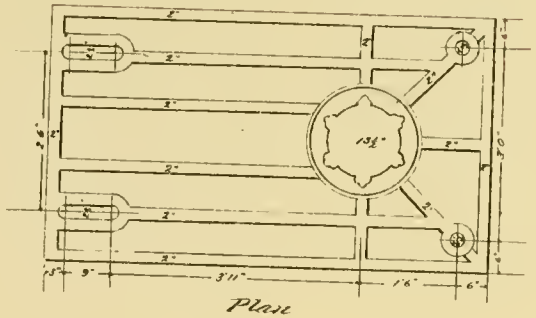
Elevation

AE, or BE, Pattern

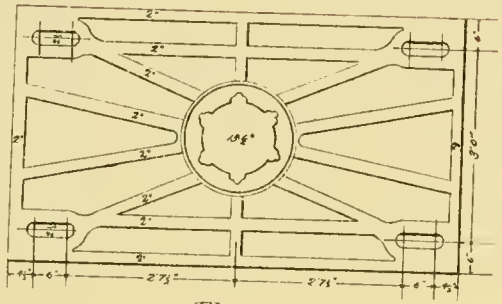


Elevation

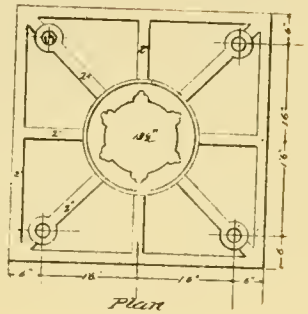
A, or B, Pattern.



Plan



Plan



Plan

Scale { 1 inch = 4 feet
1 mm = 48 mm

girders of a similar character, supported by six segment wrought-iron columns of the Phœnix pattern. The transverse girders have a double triangular system, whereas the longitudinals are of the plain triangular type. The longitudinal girders are set in pairs under each track, five feet (1.524 m.) between centres. They are four feet (1.219 m.) deep from out to out of chord angles.

The bottom chords of transverse girders are flush with the under surface of longitudinals, and made rigid therewith by plates and bolts. The transverse girders through Division and Allen streets, First avenue and Twenty-third street, are sized and fitted for the support of three tracks, and through Second avenue for four tracks.

Transverse girders weigh about 200 pounds per lineal foot (297.4 kg. per m.)

Longitudinal girders weigh about 130 pounds per lineal foot (193.5 kg. per m.)

Bracing, &c. weigh about 8 pounds per lineal foot (11.9 kg. per m.)

"A" calibre columns weigh about 350 pounds per yard (173.7 kg. per m.)

"B" calibre columns weigh about 420 pounds per yard (208.4 kg. per m.)

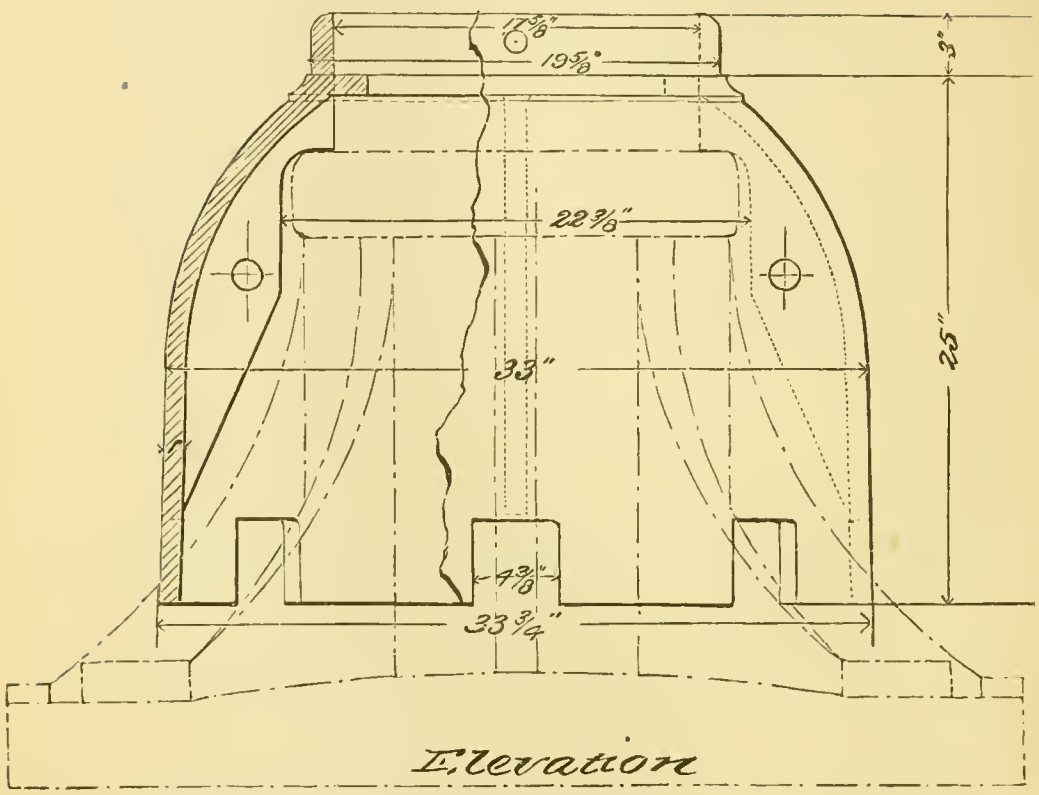
The first step in the erection of the iron work was dropping the columns into their appropriate base castings. This was easily accomplished by means of a derrick wagon, shown in Plate XVII, by which seven men and a team of horses were able to set in place an average of thirty-nine columns not exceeding 20 feet (6.096 m.) in length ; or, ten columns not exceeding 50 feet (15.240 m.) in length per diem. The space between the barrel of the base casting and the columns was then caulked with oakum to keep out the water prior to using the cast-iron cement, and the columns filled with cement mortar in proportion of two parts sand to one of cement.

The columns were held temporarily in place by inserting iron wedges inside the rim of the base casting. The girders were raised by a traveler on the structure. The power used was a 15-horse power engine, boiler shell 3′ × 6′ (.914 m. × 1.828 m.). The force needed was twelve men besides the engine man. With the power and force named the contractor raised an average of sixty-six girders per diem of ten hours, equaling 200 tons (203.22 tons kg.), using one-fourth ton (253.11 kg.) of coal. (See Plate XVIII.)

Fender

Used on 2nd Ave.

Scale 1" = 1 foot
" 1mm = 12mm



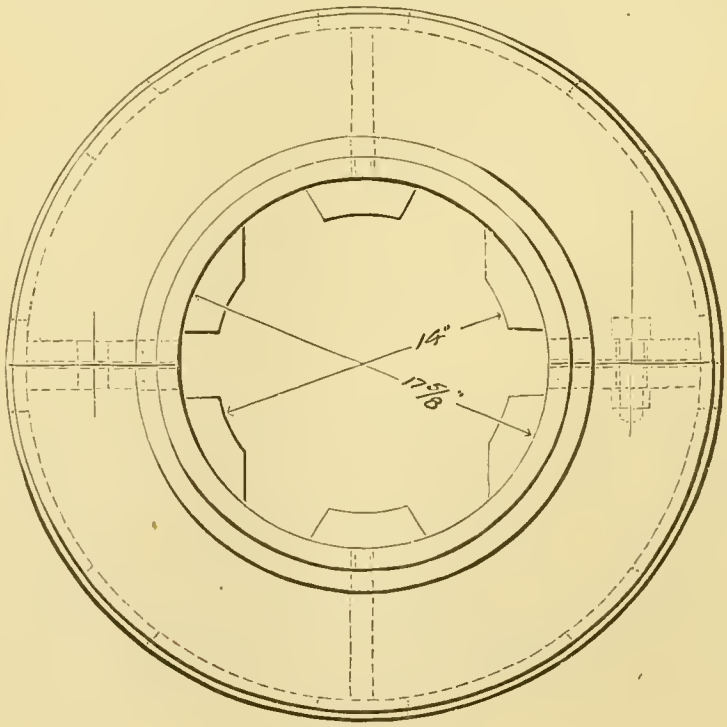


PLATE XVI.

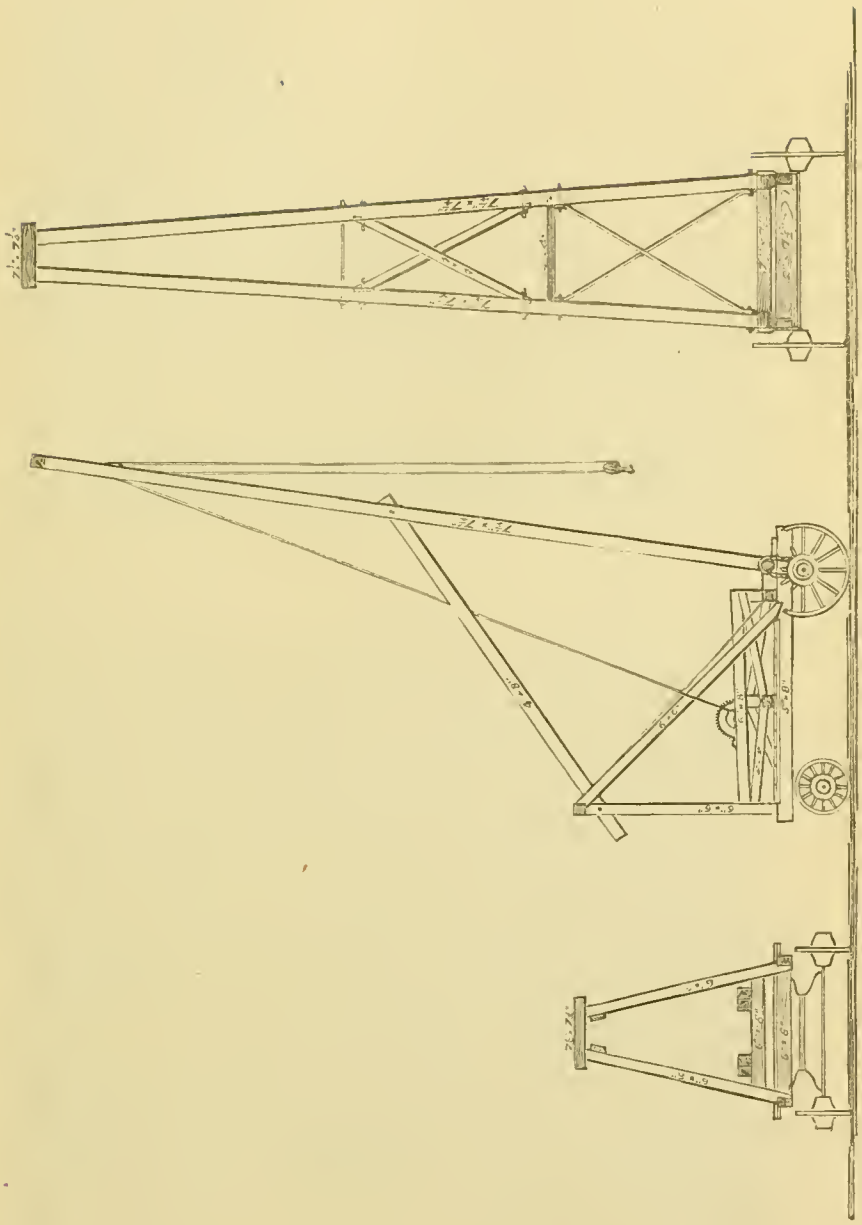


PLATE XVII.

The iron girders all being in place, the lateral bracing was then adjusted and riveted, and the columns very carefully plumbed with heavy iron plumb-bobs, and in many cases of long columns with a transit instrument. After being brought to a vertical position they were thus held by jack-screws and braces until the cast-iron cement had been substituted for the oakum.

The cast-iron cement used consisted of the following proportions: One ounce (28.3 g.) of sal-ammoniac to one gallon (3.79 l.) of water. The cast-iron turnings or borings were mixed with a minimum amount of the solution, and left standing about half an hour before using, to "warm up." The mixture was then dropped in layers of $\frac{1}{8}''$ to $\frac{1}{2}''$ (.0032 m. to .0127 m.), not to exceed the latter, and very thoroughly rammed with iron rammers driven by vigorous blows of a hammer. For a "B calibre" base about 130 pounds (58.97 kg.) of borings were required to perfectly cement the column and its base coating. For a base of "A calibre" about 100 pounds (45.36 kg.) were needed. It took about forty-eight hours to complete all evaporation, whereupon the cement became as hard as the iron itself. Much care was needed in preparing this cement. Unless sufficient water was used the cement would heat and be spoiled. The addition of sulphur one part to eight parts of sal-ammoniac hastens the process of hardening, but if time is allowed it sets more firmly without the sulphur. Hence, the use of sulphur was abandoned. It was also found absolutely necessary that the iron borings should be perfectly clean and free from rust. As an illustration of the efficiency of this cast-iron cement it may be interesting to know that when occasion offered a column was removed from a cast-iron base after it had been thus cemented, whereupon it was found stronger than the base itself, the latter breaking first under powerful blows of a sledge.

I.—Track Structure and Track Laying.

(1.) The gauge of the track on tangents is $4' 8\frac{1}{2}''$ (1.435 m.). On curves of 600 feet (182.9 m.) or less it is $4' 9''$ (1.448 m.).

(2.) The track materials consist of—

(*a.*) Southern yellow pine cross-ties $6'' \times 6'' \times 8'$ (.1524 m. × .1524 m. × 2.438 m.), except on curves, crossings and turnouts, where

PLATE XVIII
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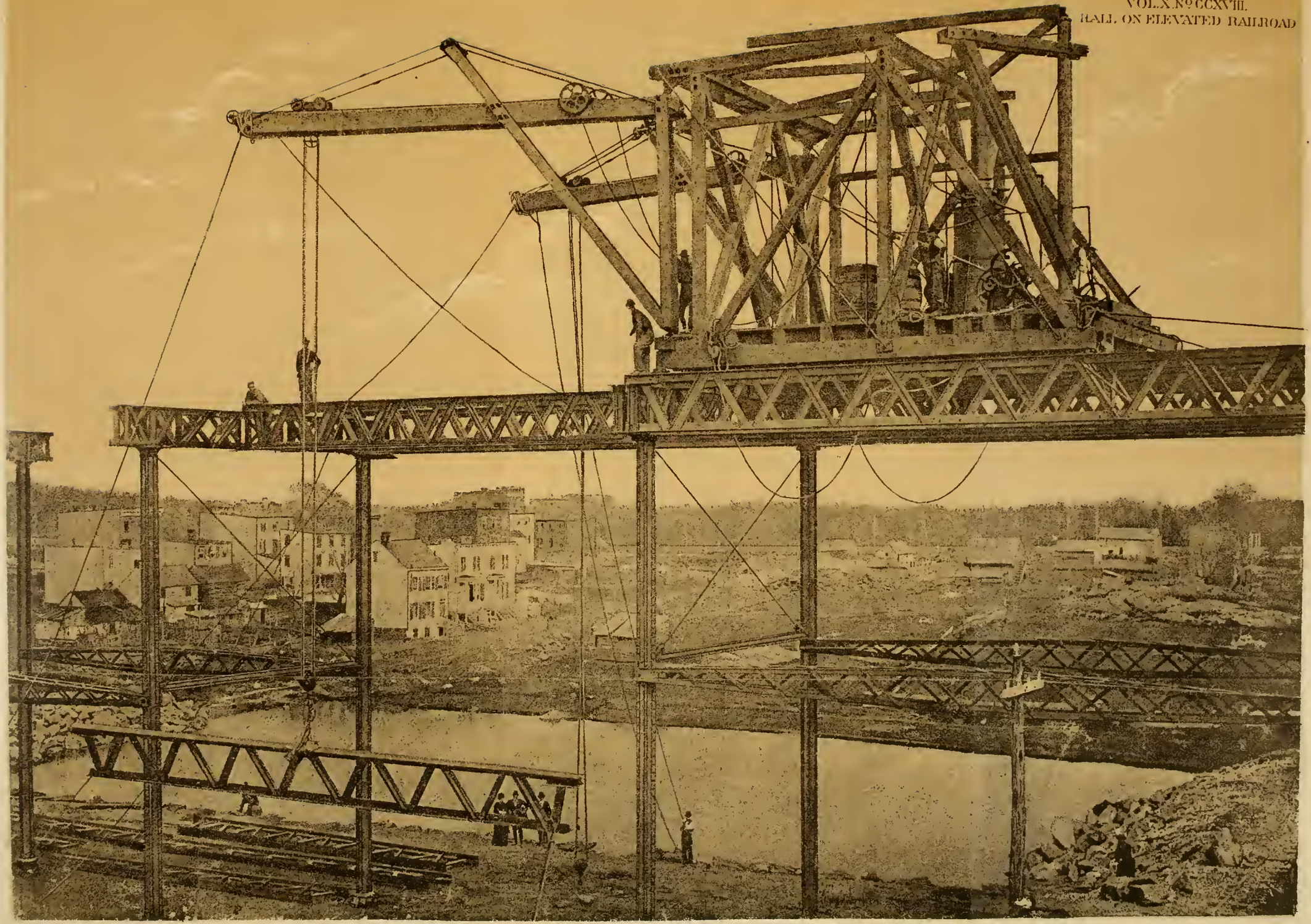

greater lengths and larger sections were frequently used. Every third cross-tie on each track of the main line is a lookout tie 12′ (3.657 m.) long.

(*b.*) Southern yellow pine guard timbers 6″ × 8″ × 30′ (.1524 m. × .2032 m. × 9.14 m) long and upwards for straight lines, and white oak guard timbers of like lengths 5″ × 8″ (.127m. × .2032 m.) section for sharp curves and their approaches.

(*c.*) White oak bevel and distance blocks, cap stringers and shims for sharp curves.

(*d.*) Steel rails weighing 63 pounds per yard (31.26 kg. per m.), and usually 30 feet (9.14 m.) long.

(*e.*) Fish plates, screw bolts, lag screws, clips, angle bar and strap-iron guards, blunt bolts, spikes and nails. All materials were delivered along the line, in the street, by the company, the contractor thereon receipting for the same and assuming all further responsibility. The accepted bids for track work were those of Messrs. D. R. Kelly, and Quinn & Flynn, all of New York City. The following table shows the amounts and respective prices credited to each :

TABLE No. 6.

CONTRACT PRICES PAID FOR TRACK WORK, AND AMOUNT DONE BY EACH.

Names.	In Lineal Feet.										Remarks.
	Tangents.		Curves.		3 Plank Walk.		Switches.		Frogs.		
	Price.	Length.	Price.	Length.	Price.	Length.	Price.	Number.	Price.	Number.	
D. R. Kelly.....	43c.	50764.4	80c.	1628	....	.....	$3 00	35	$4 00	41	Turnouts and crossings all estimated as tangents. Switches to include furniture, and in working order.
Quinn & Flynn.	35c.	37840.	....	.....	3c.	31982	12 00	23	3 00	26	
	In Metres										
D. R. Kelly.....	$1.41	15481	$2 62½	496.2	....	.....	$3 00	35	$4 00	41	
Quinn & Flynn.	1.48	11533	.....	.....	8⅛c.	9748	12 00	23	3 00	26	

II.—Straight Lines.

The cross-ties were spaced 18″ (.4572 m.) from centre to centre, excepting at rail joints, where shoulder-ties were used, spaces 6″ (.1524 m.) in the clear, from the joint tie. They were laid at right angles to the centre line of the track, with the outer ends in range. Wrought-iron clips and lagscrews were used to fasten them to the flanges of the longitudinal girders, two clips and two lagscrews to each cross-tie alternately inside and outside of the girders. The top of the cross-tie over each transverse girder was always true grade; whenever camber showed itself in the longitudinal girders it was taken out by adzing the under surface of the cross-ties. No shimming was allowed in any case. The rails are those known to the trade as "Erie Pattern," made of Bessemer steel with $\frac{35}{100}$ of one per cent. of carbon.

They were furnished by the Albany Rensselaer Iron and Steel Company, and met satisfactorily all requirements of the company's inspector. A test bar $\frac{3}{4}$″ (.019 m.) square, and one foot (.305 m.) long was taken from each charge and required to bend 80° without breaking, under a sudden pressure, on bearings of 8″ (.2032 m.) asunder. Two bars out of three to stand this test in order that the charge might be rated first class. If two out of three broke the charge was rated second class, and rejected. An official test record was kept of all charges, and open to the company's inspection. A template for section was furnished by the company. It was found that although the manufacturers were very successful, generally, in meeting the requirements of the specifications, yet it was quite common to discover a slight "kink" near the end of the rail; this could not well be avoided with the straightening machine then in use at the mills.

They are placed to break joints in each track, the ends of them, on one side, laid as nearly as possible opposite the middle of those on the other side, and the joint made exactly over the middle of the tie, each rail was then spiked with two spikes in each cross-tie. The joints were left open $\frac{1}{4}$″ (.0064 m.) when the temperature was below Fahrenheit zero: a scant $\frac{1}{4}$″ (.0064 m.) between zero and 32° : $\frac{3}{16}$″ (.0048 m.) between 32° and 50° : $\frac{1}{8}$″ (.0032 m.) between 50° and 80° ; and $\frac{1}{16}$″ (.0016 m.) above 80°. Only metal shims were used in regulating the spaces.

The guard timbers were laid both sides of the steel rails, and exactly 10″ (.254 m.) apart, the inner one being $3\frac{1}{2}$″ (.0889 m.) in the clear

from the gauge side of the track rail when complete, with strap iron. They were framed at the ends with a dovetail halving splice 9″ (.2286 m.) long, tapering one inch (.0254 m.) The splices in all four guard timbers were made to break joints; screw-bolts were used to fasten the timbers at the joints. Each guard timber was, as a general rule, bolted to alternate cross-ties, the inside and outside timbers being bolted in pairs respectively to the same tie, they were secured to the girder flanges by clips above the nuts of the screw bolts, the heads and washers of which were set down into a cup at top, bored with a 2″ (.0508 m.) auger, deep enough to sink the head slightly below the top surface of the guard timber and permit the screw end of the bolt to project about $\frac{1}{8}$″ (.0032 m.) below the nut after screwing up for upsetting. The auger-hole cup was filled completely with a paste of Portland cement, and smoothed off a little crowning to shed water, prior to painting. All the bolts used in track-work, excepting fish-plate bolts, were greased with tallow before insertion, and all meeting surfaces of track timbers and other fixtures were given a thick coat of white lead and oil paint before closing up.

III.—Curves.

The general provisions concerning straight lines governed track-work on curves as far as they were applicable. The yellow pine ties were usually 10 feet (3.048 m.) long. To give the proper elevation of the outer rail, white oak bevel caps were used for the support of rails and guard timbers. The outer rail was elevated 3″ (.0762 m.) calculated for a speed of ten miles per hour only; the elevation being gained in a distance of about 80 feet (24.4 m.) on the tangent to the curve. The track-rails were curved by templets furnished by the engineer, true to line; no springing or sledging of rails was allowed. On curves with radii of 600 feet (183 m.) and upwards each rail is held by three spikes per tie —two outside and one inside. On curves of less than 600 feet (183 m.) radius, a steel guard rail was spiked down inside of the inner track rail; it was found necessary to plane off the flanges of this rail $\frac{3}{4}$″ (.0191 m.) to permit the insertion of the screw bolts, or lagscrews; then steel guard rails were further supported and held upright in place against lateral shocks by white oak distance blocks, moulded to fit their sides, and extended nearly to the opposite guard timber, where they were "set up" by means of a wedge of oak; they were then bolted fast through the

bevel blocks and cross-ties. On top of these distance blocks were bolted through cross-tie a white oak curved cap $3\frac{3}{4}'' \times 10''$ (.0953 m. × .254 m.) section, partly covering the head of the steel guard rail; the inner face being $3\frac{1}{2}''$ (.0889 m.) from the gauge side of the inner track rail. This was guarded also on the upper edge facing the track rail by a $5'' \times 3''$ (.127 m. × .0762 m.) angle bar secured by blunt bolts. These angles were in about 14 feet (4.27 m.) lengths shaped to the curve with half check joints. The three remaining ranges of guard timbers for each track were composed of two white oak timbers, each $5'' \times 8''$ (.127 m. × .2032 m.) section clamped together sideways by bolts and lag screws, at intervals of about 1 foot (.305 m.). They were then fastened to the cross-ties as on straight lines. Both ranges of guard timbers for the outside rails on curves were faced with strap iron, the timbers being spaced $6\frac{1}{2}''$ (.165 m.) from the gauge side of the track rail instead of 6″ (.1524 m.) as on tangents. The ends of the cross-ties were then sawed off true to the curve. Figs. 1 and 2, Plate XIX, represent sections of the track for tangents and sharp curves. Owing to the fact of longitudinal girders on sharp curves being chords of the arc, and the consequent means of fastening the cross-ties varied, the different sections are more or less dissimilar.

It may be of interest to know the organization which was maintained during the construction of this novel and somewhat exceptional class of track-work. As the work was necessarily continuous, or was deemed best to be so, it was found that the most economical daily force employed should not exceed seventy men, distributed over a space of about half a mile, as follows:

15 carpenters,
10 skilled laborers to assist the same on guard timbers,
10 men laying steel rails,
10 " clipping cross-ties,
10 " spacing, marking and adzing cross-ties,
10 unskilled laborers for derrick, distributing materials, etc,
2 horses with drivers,
3 foremen.

The clippers were usually kept about 500 feet (152.4 m.) ahead of the spikers, and the spikers 750 feet (228.6 m.) ahead of the carpenters on the guard timbers. Horse power was found to be cheaper and of more practical utility than steam in hoisting track material. The cross-ties

PLATE XIX
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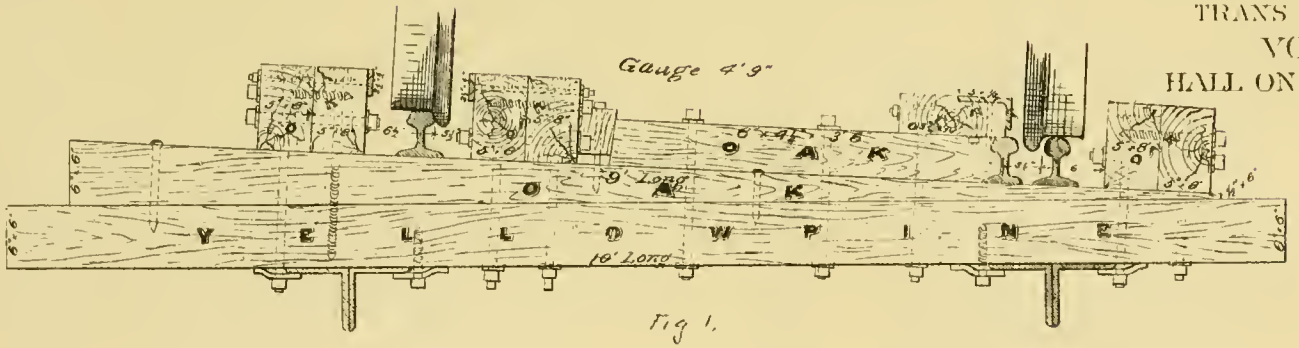


Fig 1.

Scale 1" = 2 feet
1mm = 24mm

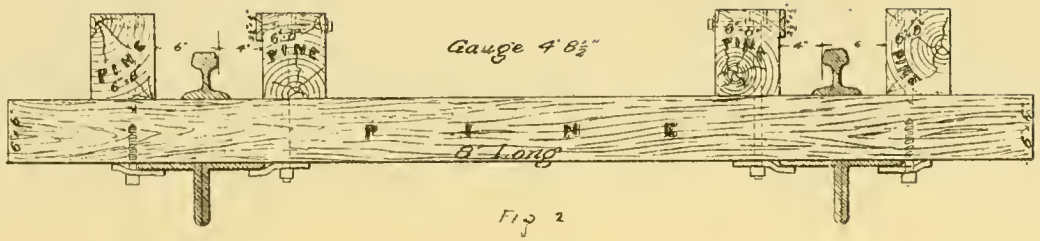


Fig 2

were first hoisted, distributed and spaced; then marked for camber by means of T sights, adzed and clipped. Then the steel rails were in turn distributed, lined up and spiked; then the guard timbers were distributed, ends jointed, gauged and bolted down; the inside guard being put in place and finished with strap iron before the outside one was laid. A space of about 250 feet (76 m.) intervened between the gangs employed on the two ranges of guard timbers. Everything working smoothly, the above force accomplished about one block or 260 feet (79.25 m.) of double track *per diem* of ten hours, on tangent work.

The following statement gives the actual cost to contractors Quinn and Flynn of laying complete one thousand lineal feet (304.8 m) of straight single track :

Hoisting and distributing materials.....	$40 00
Laying cross-ties.....	65 00
Hoisting steel rails.....	30 00
" guard timbers.....	100 00
Strap ironing guard timbers.....	20 00
Incidentals, loss of time, repairing tools, etc....	25 00
Superintendence.....	20 00
	$300 00
Amount paid contractor as per prices bid.....	350 00
	$50 00 Profit.

or $16\frac{2}{3}$ per cent.

The amount of materials required for the construction of one thousand feet (304.8 m) of single track, is as follows :

250 cross-ties, 6″×6″×12′ (.1524 m.×.1524 m.×3.658 m.).
500 " 6″×6″×8′ (.1524 m.×.1524 m.×2.438 m.).
3 000 wrought iron clips $5\frac{1}{2}$″×$2\frac{1}{2}$″ ×$\frac{1}{2}$″ (.1397m.×.0635 m.×.0127 m.)
1 500 lag screws, 6″×$\frac{3}{4}$″ (.1524 m.×.0191 m.).
67 steel rails, 30′ (9.144 m.) long.
67 fish-plates, 20″×$2\frac{1}{2}$″×$\frac{3}{4}$″ (.5082 m.×.0635 m.×.0191 m.).
268 " " bolts, 4″×$\frac{3}{4}$″ (.1016 m.×.0191 m.) with nuts and washers.
3 000 spikes.
7 000 lineal feet guard timber, 6″×8″ (.1524 m.×.2032 m.).
1 500 guard rail bolts, nuts and washers, $14\frac{1}{2}$″×$\frac{3}{4}$″ (.3664 m.×.0191 m.).
150 lag screws, 12″×$\frac{3}{4}$″ (.305 m.×.0191 m.).

2 000 lineal feet strap-iron, $2\frac{1}{2}'' \times \frac{1}{2}''$ (.063 m. × .0127 m.) section.

300 strap iron bolts, $6\frac{1}{2} \times \frac{1}{2}''$ (.1651 m. × .0127 m.) with nuts and washers.

300 blunt bolts for strap-iron, $5'' \times \frac{1}{2}''$ (.127 m. × .0127 m.).

$\frac{3}{4}$ barrel Portland Cement.

Turnouts and Crossings.

To lay one typical crossing, as shown in Plate XX, consisting of 218 lineal feet (66.5 m.) of track, with five frogs, from switches and outside guard timbers, with inside steel guard rails, costs as follows:

Hoisting, adzing and clipping cross-ties	$18 25
Laying rails, frogs and switches	40 00
" guard timbers	12 50
" steel guard rails	4 25
Total	$75 00
Amount paid contractor as per prices bid	139 30
Profit	$64 30

or $85\frac{7}{10}$ per cent.

Sidewalks Three Planks Wide.

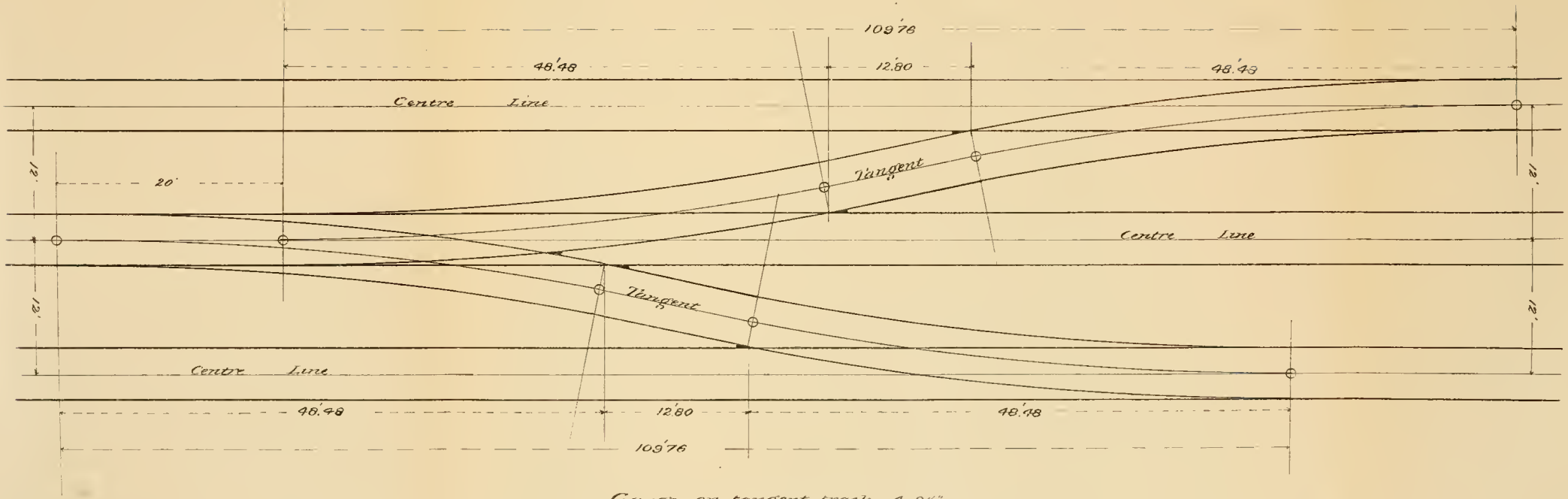
Cost to contractor per 1 000 lineal feet (304.8 m.)	$15 00
Amount paid contractor as per prices bid	25 00
Profit	$10 00

or $66\frac{2}{3}$ per cent.

Painting.

In mixing paints for iron surfaces, it is of the first importance that the best materials only be used. Linseed oil is the best medium, when free from admixture with turpentine, the latter being a volatile oil, cannot be used with advantage on a non-absorbent surface. Linseed oil, however, is peculiarly well adapted for this purpose. It does not evaporate in any perceptible degree. The large percentage of linolein which it contains combines with the oxygen of the atmosphere, and makes the surface of the paint solid and of a resinous appearance, possessing toughness and elasticity. Linseed oil does not crack or blister, by reason of the expansion and contraction of the iron with variation of temperature. Another important characteristic is its expansion while drying, which peculiarly

Typical Crossing
used on
2nd Ave. Line
M.R.R.
Scale 1in = 10ft.
" 1mm = 120 mm.



Gauge on tangent track 4' 8½"
" curved 4' 9"
Frog Angle 11° 4' 30"
Middle Frog Angle 14° 12' 0"
Radius = 250'
Point of switch 6" ahead of point of curve.

adapts it to iron surfaces. The Metropolitan Elevated Railway Company spent no small amount of money in experimenting with various classes, kinds and colors of paint, before arriving at a final conclusion; their labors at last culminated in the selection of a metallic paint for the first coat, and a white lead paint for the second and last coat, both paints to be mixed with the best boiled linseed oil, and enough turpentine to make the paint cover well and facilitate its drying. The following formulæ were therefore adopted and adhered to:

(1.) Metallic Paint.

9 parts of boiled linseed oil.

1 part of turpentine.

7½ pounds of "metallic" (ground iron ore).

Made one mixed gallon (3.79 l) of paint, and covered about 256 square feet (23.78 sq. m).

(2.) White Lead Paint, Olive Color.

325	pounds	(147.42 kg.)	white lead.
175	"	(79.38 ")	white lime.
75	"	(34.02 ")	French ochre.
3	"	(1.361 ")	Prussian blue.
1	pound	(.454 ")	burnt umber.
21	galls.	(79.50 l.)	boiled linseed oil.
1½	"	(5.678 l.)	turpentine.
1	"	(3.79 l.)	liquid drier.

Made 751 pounds (340.64 kg.) or 18 gallons (68.13 l.) of mixed paint, and covered about 512 square feet (47.56 sq. m.).

The iron work was first thoroughly cleaned, rough spots scraped, and such spots, together with all new rivets or other raw details, were "touched up" with one coat of metallic paint.

All the seams in top and bottom chords, gaps at brace joints, and all other cracks or seams needing it, were filled solid with linseed oil putty. The top surface of the top chords was then given one coat of metallic paint. The strap-iron, clips, fish-plates and under side of cross-ties, steel rails, and guard timbers, were painted one coat of same before adjustment. All cracks, joints, sun checks, &c., in the timber, were filled with putty prior to painting with metallic paint and again before using the white lead color.

The track superstructure received two coats of metallic paint. All track work being finished and the whole structure complete, the final

covering of white lead paint was laid on with great care, under close inspection, and has proved, so far, to be the desideratum for iron surface painting. The actual cost of painting the structure, including the station girders, but not their buildings, with all the details of scraping, cleaning, puttying, together with all materials and labor was $1 50 per lineal foot.

The labor account was $36\frac{8}{10}$ per cent. of the total cost.

While the material account was $63\frac{2}{10}$ per cent. of the total cost.

Appendix.

Form of estimate sheet of special street pier, built January, 1881, showing the exact construction, character of material in excavation, quantities, contract prices paid, and the total cost of the pier as ready for the column at connection with Harlem River Bridge, north end of Eighth avenue. (See Plate XXI.)

Nature of bottom—silt.

Bottom stones set—2, (7′×3′×6″).

Bolts—4–10′ 4″ = 472 lbs.

Washers—4 = 108 lbs.

Base set—1 = 3200 lbs.

Refilling (62.59+73.11) – (13.49+16.92+22.67) = 82.62 Cu. yds.

Excavation:

Earth—13′×13′×10′ = 62.59 cu. yds.

Loose rock—13′×13′×11′.68 = 73.11 cu. yds.

Pitwork—13′×13′×12′.93 = 80.93 cu. yds.

Piling—16 – 50′ = 800 lin. ft.

Capping—4 – 9′×6″×12′, 18 – 9′×6″×6″ = 702 ft., B. M.

Concrete—12′×12′×4′.25=83.46 cu. ft. Grillage = 19.58 cu. yds.

Brickwork:

Pier—4′ 6″ squ.×8′ 0″ sq.×9′.083 — 21 cu. ft. (bottom stones) = 12.71 cu. yds.

Sub-pier—8′×8′×7′.14 = 16.92 cu. yds.

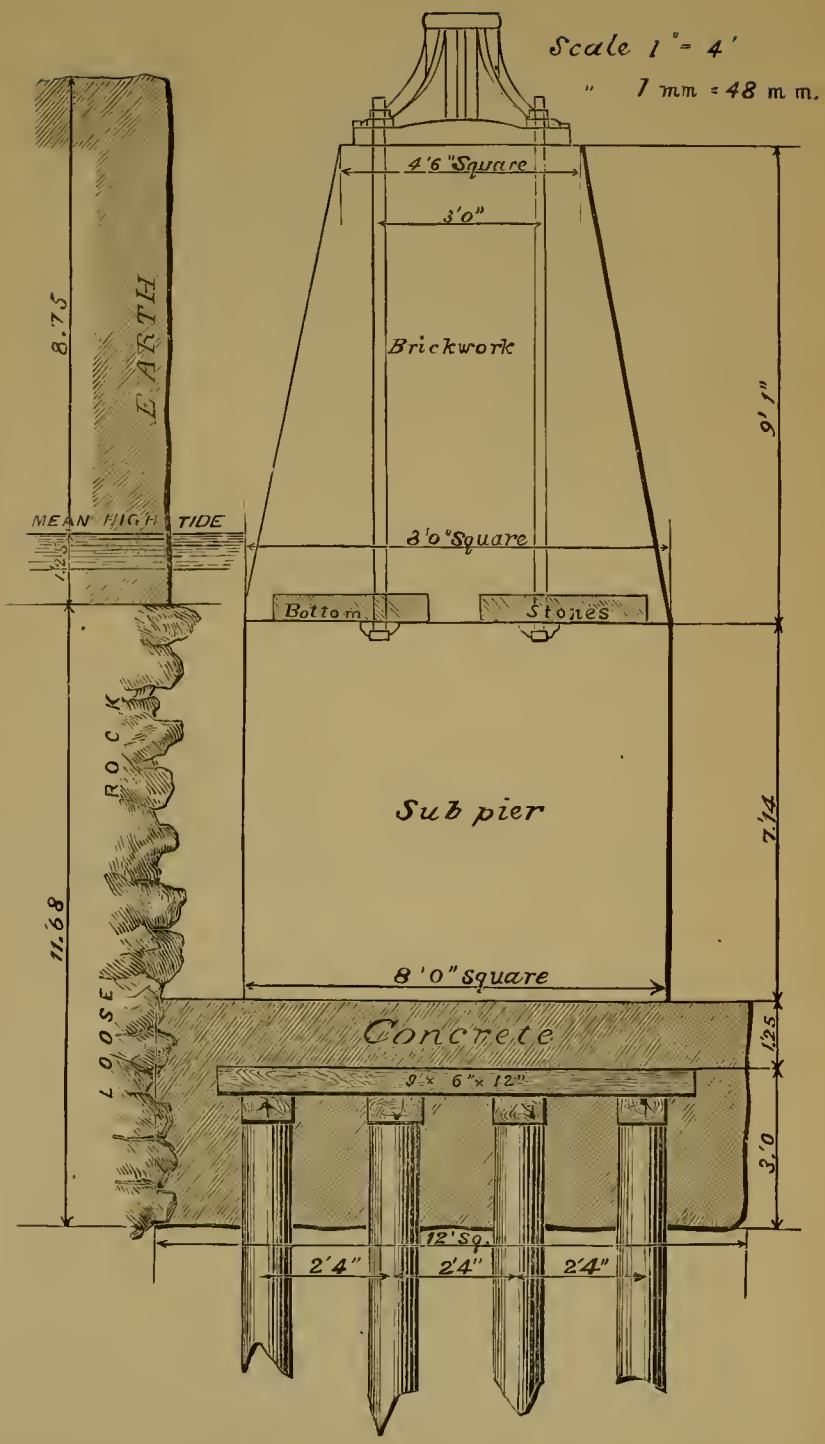
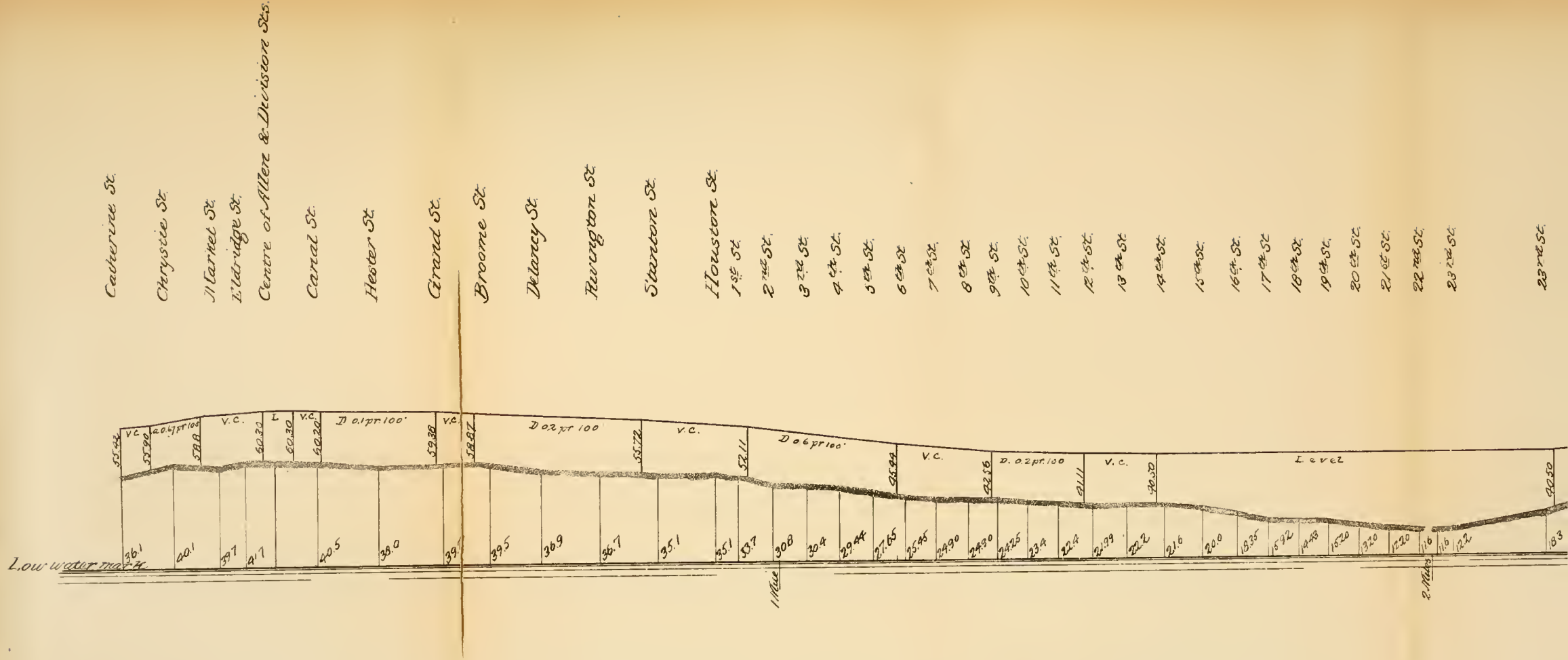

Scale 1" = 4'
" 1 mm = 48 m m.
4'6" Square
3'0"
Brickwork
9'1"
8.75
EARTH
MEAN HIGH TIDE
1.25
3'0" Square
Bottom
Stones
Sub pier
7.14
11.68
LOOSE ROCK
8'0" square
Concrete
1.25
9" × 6" × 12"
3.0
12' sq.
2'4"
2'4"
2'4"

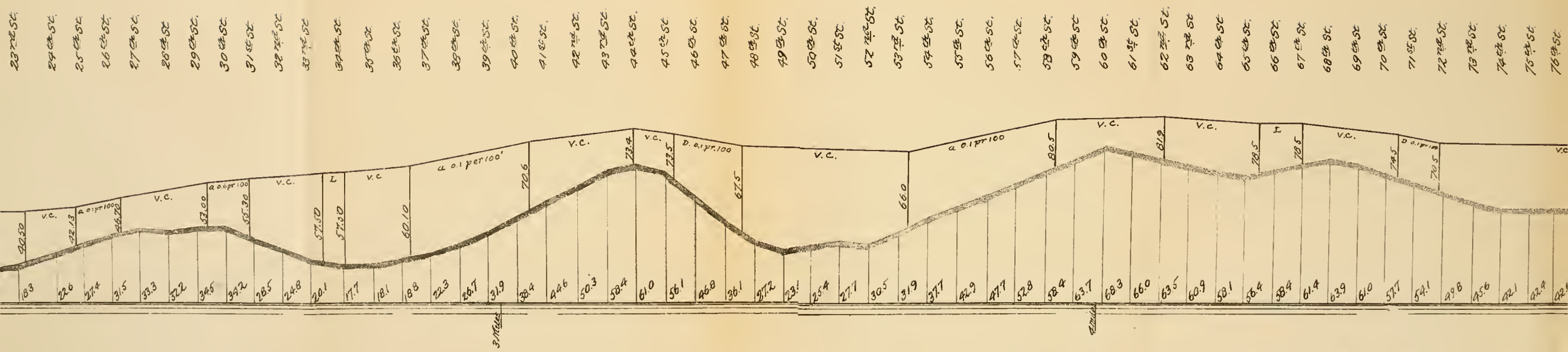
PLATE XXI.

Estimate of Work Done and Materials furnished by M. Tierney, Contractor.

Quantities.	Items.	Amount.	Remarks.
62.59 cu. yds...	Earth Excavation @ $1 50....	$93 89	The iron and bottom stones were furnished by the company.
73.11 " " ...	Loose Rock Excavation @$3 00	219 33	
80.93 " " ...	Pitwork @ $2 00.....	161 86	
800.—lin. ft....	Piling @ $0 30.....	240 00	
702.—ft. B. M..	Capping @ $35 00 pr. M.....	24 57	
19.58 cu. yds...	Concrete @ $5 00.....	97 90	
29.63 " ...	Brickwork @ $9 00.....	266 67	
2.....	Bottom Stones @ $2 00.....	4 00	
1.....	Base set.....	4 00	
82.62 cu. yds...	Refilling @ $0 10.....	8 26	
	Total.....	$1 120 48	



Catherine St.
Chrystie St.
Market St.
Eldridge St.
Centre of Allen & Division Sts.
Canal St.
Hester St.
Grand St.
Broome St.
Delancy St.
Rivington St.
Stanton St.
Houston St.
1st St.
2nd St.
3rd St.
4th St.
5th St.
6th St.
7th St.
8th St.
9th St.
10th St.
11th St.
12th St.
13th St.
14th St.
15th St.
16th St.
17th St.
18th St.
19th St.
20th St.
21st St.
22nd St.
23rd St.
23rd St.
V.C.
D 0.1 pr. 100'
D 0.2 pr 100
D 0.6 pr 100'
D. 0.2 pr. 100
Level
Low water mark
1 Mile
2 Miles



PROFILE

2nd Avenue Line, Manhattan Railway

Scale { Horizontal
Vertical

PLATE XXII
TRANS AM SOC CIV ENGR'S
VOL X No CCXVIII.
HALL ON ELEVATED RAILROAD

Co.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852.

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CCXIX.

(Vol. X.—April, 1881.)

EXPONENT OF THE PRINCIPLE OF MOMENTS.

By W. S. AUCHINCLOSS, Member of the Society.

READ MARCH 2D, 1881.

The processes of mathematics and mechanics have, in many respects, mutual relations, like those existing between force, light and heat. Many of the formulae of mathematics find direct expression in mechanical devices, so that the mind naturally glides from one to the other. The greater the attention paid to this characteristic, the clearer will the principles of mathematics appear, and the more marked the rapidity with which solutions can be effected.

The averaging machine, illustrated herewith (see Plate XXIII), is an exponent of the "Principle of Moments." In the development of this machine, the first effort was to determine a simple rule for computing average dates. For this purpose the "Principle of Moments" was found applicable, and a rule constructed thereby. The next step was to give mechanical expression to the rule. This has been secured by the device represented in the adjoining cut.

The machine consists of a scale and a series of weights. The scale, when not ladened, maintains its equilibrium *irrespective* of the position of the scale pan. The arm of the beam has 31 notches, representing the days of the month, and the scale pan is hung on a small saddle, capable of being moved from end to end of the beam. A carrier bar is fastened directly over the scale arm, and upon it a counterweight slides freely. This counterpoise exactly equals in weight the scale pan with its saddle. Two delicate watch chains are attached to opposite sides of the counterweight. They pass around little carrier wheels secured to the extremities of the arm, and are fastened to opposite sides of the saddle. In this way the saddle and the counterweight become, as it were, links in an endless chain, so that the counterpoise responds instantly to the slightest motion of the scale pan, and maintains the equilibrium of the system, for all positions of the same. By this device the weight of the pan is no longer a factor in the problem, but in effect the pan is rendered imponderable. The two balls shown at the extremity of the scale arm are used simply for purposes of adjustment as customary on all scales. Directly over the fulcrum are the usual index pointers. The platform of the scale has 31 transverse groves. These are arranged equidistant, and are capable of receiving the weights. The platform is hinged to the opposite arm of the scale, and is surrounded by a metallic fence, that is shaped like a spout on the far side. This spout serves to guide the weights in their descent to the separator, after the solution of any problem. Each groove is properly numbered from 1 to 31, inclusive, to correspond with the numbers on the scale arm. The various problems of "average date" are determined by the use of five varieties of weights shown in the cut, under letters *A*, *B*, *C*, *D* and *E*. The *A* and *C* balls are made of lead. The *B* and *D* cylindrical bodies are made from wrought-iron rods. All of these weights are nickel-plated to prevent soiling the hands. Each ball, *C*, is equal in weight to 10 balls of *A*, while each weight, *E*, is equal to 10 of *C*. In this way *A*, *C* and *E* may represent; units, tens and hundreds; or 10, 100, 1 000; or 100, 1 000, 10 000; and so on; expressing as the occasions requires, whole numbers or decimals. The weights *B* and *D*, are used simply for the purpose of economizing time. One of *B* equals 5 of *A*, and one of *D* equals 5 of *C*. The use of these intermediates saves tedious counting of the balls, *A* and *C*, and their characteristic form prevents possibility of mistakes.

It remains only to describe the separator before explaining the mode of using the machine. The separator is located directly under the platform. The balls, when dumped by the latter, are received on an inclined plane, which is covered with rubber to deaden the sound. This incline causes the balls to roll to the front part of the machine, where they fall upon a wire screen. This is of suitable size to allow *A* balls to drop into their own compartment, but retains the *C* balls, thus effecting a perfect separation. The weights *B* and *D*, should be lifted from the platform and lodged in cups on the right and left of the separator.

When it is required to determine the average date of a number of purchases made during any month, it is only necessary to place weights representing the amounts purchased in the grooves representing the days, fill the scale pan with exactly the same amount of weight as placed on the platform, then move the pan along the scale arm until the weights in the pan *exactly balance* those on the platform. The reading of the scale arm will give the "average date" of the purchases to which 30, 60 or 90 days must be added according to terms of sale.

The woodcut shows but one form of averaging machine, but as occasion requires, the number of grooves can be greatly increased and the machine adapted to various requirements.

The machine can be used for solving a great variety of problems, by varying the grooves, notches and weights. If, for instance, a vertical line passing through the fulcrum is made to exactly divide the system of grooves and notches, so that all are equidistant, and no blank spaces intervene between the line and the No. 1 groove, or the No. 1 notch; then the machine will solve a vast variety of problems of direct and inverse proportion; as for instance, the diameters and speeds of pulleys; the diameters, circumferences and areas of circles, of ellipses, and so forth. With speed problems it is only necessary to let the grooves of the platform represent the diameters of the large pulleys, and the notches on the arm the diameters of the small pulleys; whereupon the speed of the large pulley, will be represented by whatever weight placed in the groove will balance the weight in the pan, which latter represents the speed of the small pulley. It is evident that if any three quantities are given, the fourth can at once be determined.

Again, if the distance of any groove from the fulcrum be taken as unity, and the scale pan located at a distance in the opposite direction equal to 3.14159+, then any weight in the pan that will balance a given

weight in the groove will represent the diameter of a circle ; while the weight in the groove will represent the circumference of the same circle.

By using weights of different specific gravities in the pan and on the platform, or else by using specially graduated scales, problems in square root can be determined with like facility.

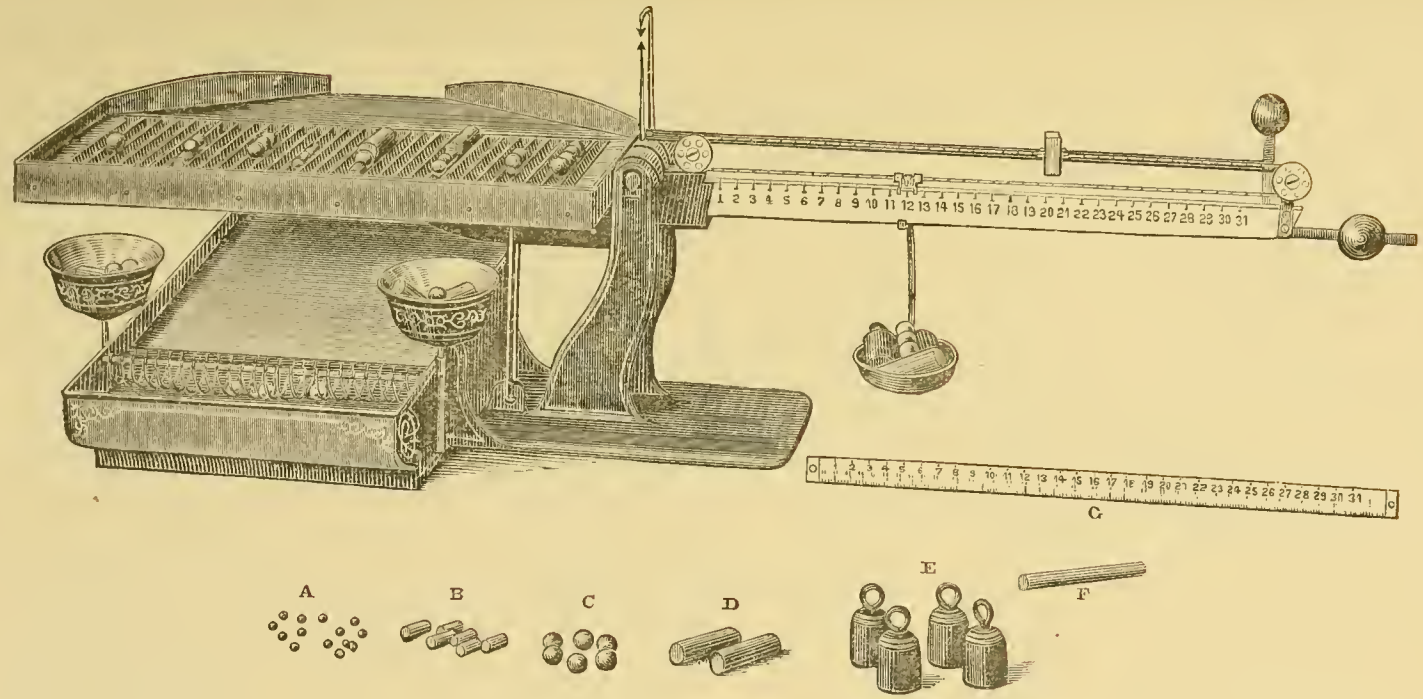
For every day services these capabilities are of little moment, as compared with the process from which the machine derives its name. They are, however, of interest to the student, for they clearly illustrate the intimacy of the relation existing between the processes of mathematics and mechanics.

In the matter of averaging commercial accounts, the machine leaves the workings of the mind far in the distance, for by its aid one can solve 100 accounts per hour without fatigue, or uncertainty as to results. The machine has an additional advantage, for it can be successfully operated by those who have but little skill with figures.

The writer ventures the opinion that *for every formula or rule in mathematics* (possibly excepting higher mathematics) *a suitable mechanism can be devised which will perfectly illustrate and express the same.*

It is not claimed that in every class of problem the extreme precision of a mathematical solution can be attained, for as a matter of expense, it may not be expedient to seek a perfection of adjustment that will insure such results. This is illustrated in the case of the averaging machine. It would be possible to adjust it with the perfection found alone in an assayer's balance, so that the wing of a fly, or even the scratch of a pencil would affect the equilibrium, but the outlay would be entirely unnecessary ; and what would it signify ? The machine might indicate a certain payment should be made at 3.30 A. M., when in practice no one could be found, at that early hour, either to pay or to receive the money.

It may be objected, that the machine does not, in the case of heavy transactions, take notice of amounts less than ten dollars. This is true, but there is no reason why weights should not be made to represent any desired amount. It is equally true that the influence of such weights on the final result would scarcely be appreciable ; and, at most, would only modify it a few hours in time. Practice will, in all cases, indicate what degree of mechanical nicety should be attained in the construction of any machine.



AVERAGING MACHINE.

PLATE XXIII.

PATENTED DEC. 21, 1880.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CCXX.

(Vol. X.—May, 1881.)

WIND PRESSURE UPON BRIDGES.

By C. SHALER SMITH, Member A. S. C. E.

READ DECEMBER 15TH, 1880.

WITH DISCUSSIONS

By CHARLES DOUGLAS FOX, ROBERT E. JOHNSTON, G. BOUSCAREN, WILLARD S. POPE, JOSEPH M. WILSON, A. GOTTLEIB, D. J. WHITTEMORE, A. S. C. WURTELE, CHARLES A. SMITH, ROBERT FLETCHER and O. CHANUTE.

It may be safely stated that the practice among American engineers is very nearly uniform in regard to wind strains. My own specifications, which I have used in constructing a number of exceptionally high bridges, some of them in especially exposed positions, are as follows:

[NOTE.—The substance of this paper was embodied in a letter written in response to a request from the Secretary of the American Society of Civil Engineers. The occasion of this request was to obtain a statement of the practice of American engineers in regard to wind strains, and to secure this the Secretary corresponded with a number of the members of the Society who had large experience in the construction of bridges. Extracts from the letters of these members were transmitted to Sir John Hawkshaw, Hon. Member A. S. C. E., who had asked the Secretary to obtain this information for the use of a Commission upon the subject in England. With the consent of Mr. C. Shaler Smith, the substance of his letter is issued as this paper.—EDITOR.]

"The portal, vertical and horizontal bracing shall be proportioned for "a wind pressure of 30 lbs. per square foot on the surface of a train "averaging 10 square feet per lineal foot, and on twice the vertical sur- "face of one truss. The 300 lbs. pressure per lineal foot due to the train "surface shall be treated as a moving load, and the pressure on the trusses "as a fixed load. Trusses of less than 200 feet span shall also be propor- "tioned for a pressure of 50 lbs. per square foot when unloaded, and the "greatest strain by either method of computation shall in each case be "used in determining the sectional areas of the bracing.

"Iron piers, and spans carried by them, shall be designed to resist "a wind force of 30 lbs. per square foot on train and structure, or 50 lbs. "per square foot on the structure alone. The compressive strains on the "leeward columns of the piers shall be computed with the assumption "that the maximum load is on the bridge, and to these shall be added "the compressive strains produced by the wind, and the columns shall "be proportioned to resist these combined strains with a factor of safety "of four. The minus strains on the windward columns shall be com- "puted with the lightest train on the bridge which will not be blown off "by a wind force of 30 lbs. per square foot, and such a width of base "shall be given to the pier that there shall be no tension in any of the "columns composing it.

"If the bridge is on a curve, the centrifugal force due to the max- "imum load moving at forty miles per hour shall be added to the strains "arising from wind pressure on span and pier. To resist the strains "computed as above specified, tensile bracing shall be proportioned at "15 000 lbs. per square inch; the shearing sections of pins, bolts and "rivets, at 10 000 lbs. per square inch; rivets in tension at 5 000 lbs. "per inch; bending stress of pins at 22,500 lbs. per square inch, "and struts in compression with a factor of safety of four. The end con- "nections of all wind bracing shall be stronger than the bracing itself. "Joints of pier columns shall be fully spliced, so that not less than one- "half of the sectional area of the column is available for a tensile strain. "In case the sectional area of a pier column proportioned for the load, "wind and centrifugal strains combined, with a factor of four, is less "than the section required for load and centrifugal strains only, at the "specified factor for load stress, the largest section shall be used in all "cases.

"To all strains computed as above for wind bracing there shall be

"added an initial stress of 10 000 lbs. in each member, in order to allow "for the strains produced in screwing up the rods during the adjustment "of the bracing." * * *

Two features in the foregoing require explanation :

First—Relating to the area of exposed surface, my experiments on the Rock Island pivot span in 1872 showed that the resistance to wind by the structure was that due to rather more than 1 $\frac{8}{10}$ times the exposed surface of one truss.

Last—The wind pressure on the train is treated as a rolling load because the action of lateral shear on wind bracing is precisely the same as that of vertical shear on the web members, *i. e.*, greatest with partial loads.

The following railways and bridge companies use practically the same specifications as the foregoing :

Chicago, Milwaukee & St. Paul Railway.

Cincinnati Southern Railway.

Keystone Bridge Company, of Pittsburgh.

St. Louis, Kansas City & Northern Railway.

Denver & Rio Grande Railway.

Atchison, Topeka & Santa Fé Railway.

St. Paul, Minneapolis & Manitoba Railway.

Gulf, Colorado & Santa Fé Railway.

Many engineers prefer to express wind force in pounds per lineal foot of bridge instead of per square foot of exposed surface. Using a 200 feet span as an example, the specifications in question can be condensed as follows :

Fixed load in plane of roadway, 210 lbs. per lineal foot.

" " in plane of other chord, 130 lbs. per lineal foot.

Moving load in plane of roadway, 300 lbs. per lineal foot.

Iron in tension, 15 000 lbs. per inch.

Iron in compression; factor, 4.

The Erie Railway specifications are as follows :

Fixed load, roadway chord, 150 lbs. per lineal foot.

" " other " 150 " " " "

Moving load, roadway " 300 " " " "

Iron in tension at 15 000 lbs.

" " compression, factor 4.

The Greenville & Columbia Railway specifications are the same as

the Erie, except that 200 lbs. per foot are used for the top chord of through bridges.

The Louisville & Nashville specifications are the same as Erie, but no moving load is used—simply 450 lbs. per foot on roadway bracing and 150 lbs. per foot on the other chord.

The Lake Shore road uses 300 lbs. per foot fixed load on roadway laterals and 150 lbs. on the other chord, but strains in tension are 10 000 lbs. per square inch only.

The Chicago, Rock Island & Pacific Railway prescribes 300 lbs. per foot, with iron at 10 000 lbs. per inch.

The Pittsburgh, Cincinnati & St. Louis Railway requires 300 lbs. per foot for the train and 30 lbs. per square foot on one truss only.

The Louisville Bridge Company uses the same specifications as the Louisville & Nashville Railway.

For the bridge over the Missouri, at Glasgow, 50 lbs. per square foot on one truss and 300 lbs. per foot for train were used.

For the Eads bridge, at St. Louis, 50 lbs. per square foot on the structure alone was the specified pressure.

For the Kentucky River Bridge the wind pressure was assumed at 31½ lbs. per square foot on spans, train and piers, and factor four was used in proportioning the bracing.

The Portage Bridge, in New York, was built to resist 30 lbs. per square foot on structure and train, and 50 lbs. per square foot on the structure alone.

Both of these last bridges are unusually lofty and in exposed positions, and both are on iron skeleton piers.

The 520 feet span over the Ohio, at Cincinnati, was designed to withstand 50 lbs. per square foot on structure alone, or 30 lbs. per foot on train and structure combined.

Thirty lbs. per square foot was recommended by the majority of the members of the Committee on the "Means of Averting Bridge Accidents," in their report to the American Society of Civil Engineers in March, 1875. One of that Committee, however—General Ellis—advised 40 lbs. per square foot, which specification is also used by Mr. Slataper, Chief Engineer of the Pennsylvania Railway Company.

Having given the foregoing examples as a fair average of the current practice of American engineers in regard to wind pressure, I will add the data on which I base the opinion that the specifications first recited

fulfil all the requirements of the case, even in what is known as the tornado belt of our Western States.

For a number of years past, whenever practicable, I have personally visited the tracks of destructive storms as soon as possible after their occurrence, for the purpose of determining the maximum force and width of the path in each case.

The most violent on my records are as follows :

First.—East St. Louis, 1871 : Locomotive overturned ; maximum force required, 93 lbs. per square foot.

Second.—St. Charles, 1877 : Jail destroyed ; force required, 84.3 lbs. per square foot.

Third.—Marshfield, Mo., 1880 : Brick mansion house levelled ; force required, 58 lbs. per square foot.

Fourth.—Havre de Grace, Md., 1866 : Ten spans wooden Howe truss bridge, 250 feet each, blown over ; force required, 27 lbs. per square foot.

Fifth.—Decatur, Alabama, 1870 : Two spans of Combination Triangular truss blown over ; force required, 26 lbs. per square foot.

Sixth.—Meredosia, Ill., 1880 : One span wooden Howe truss, 150 feet long, overturned ; force, 24 lbs. per foot.

Seventh.—Omaha, Nebraska, 1877 : Two spans iron Post truss, 250 feet each, blown down ; force required, $18\frac{7}{10}$ lbs per square foot.

Also, sundry cases of train derailment caused by wind, the maximum force required being $30\frac{1}{2}$ lbs. per square foot.

In each of the foregoing cases I have given what appeared to be the maximum effort of the wind and the lowest pressure required to produce the observed result. It is therefore not unlikely that the real force of the wind in each example was greater than I have stated it. Some of the tornadoes were very destructive—the Marshfield one, for instance, having cut a swath 46 miles long and 1800 feet wide, and killed and wounded over 250 people. To the above cited instances may be added the Tay Bridge disaster, in which case $20\frac{4}{10}$ lbs. per square foot on train and bridge were required to destroy the piers, through the rupture of the vertical bracing in the four bottom tiers of the pier over which the train was passing when failure began. My reasons for considering 30 lbs. per square foot sufficient for a working specification, when the above record shows much higher pressures, are these—

First.—I very much doubt if a *direct* wind or gale ever exceeds 30 lbs.

per foot; whirlwinds do exceed it, but the width of the pathway of maximum effort in these is usually very narrow, although the general direction is so erratic that the appearance of the *debris* is generally such as to produce the impression that the vortex was much larger than was really the case. With the exception of the Marshfield tornado, I have yet to find a storm swath where the width of pathway wherein the force exceeded 30 lbs. per square foot, was more than 60 feet wide.

The St. Charles tornado is a case in point. This whirlwind cut a swath about 1000 feet wide for 14 miles, and destroyed over 300 houses, exerting a force of over 84 lbs. per square foot at its point of maximum effort. It crossed the middle span of the St. Charles bridge nearly at right angles, and developed a pressure of $52\frac{4}{10}$ lbs. per square foot in picking up and crushing a barrel of tar, which stood on the bridge in the path of the vortex. The width of the vortex was distinctly marked on the span by the circle in which the tar was spun around, the wreckage left upon it, and the points at which it ceased to destroy the flooring. This width was thus shown to be slightly over 60 feet, and, guided by this, I was subsequently enabled to locate the path traveled by the central vortex throughout the entire length of the storm swath. The bridge itself was uninjured, although it was only proportioned to withstand 30 lbs. per square foot, with a strain of 20,000 lbs. per square inch on the braces. This span was 320 feet long, 30 feet in depth, and the top chord was 120 feet above the water. I consider it very unlikely that a bridge of over 200 feet span will ever be exposed to a wind force of more than 30 lbs. per square foot, acting *in the same direction* over its entire length.

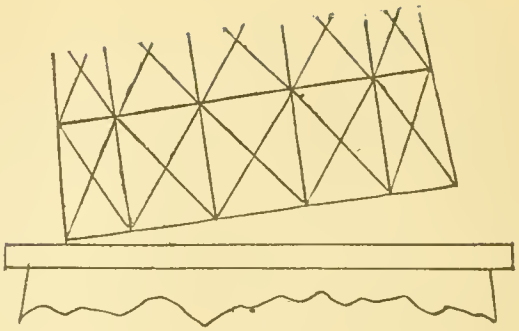
Next.—A fully loaded passenger train, and the heaviest possible freight train will leave the track at the respective pressures of $31\frac{1}{4}$ and $56\frac{1}{2}$ lbs. per square foot. If the braces are proportioned at 15,000 lbs. per square inch, with a wind pressure of 30 lbs. per square foot, they will still be within their limit of elasticity at the moment when the train is blown from the track in either case. Destruction of the span will then take place, if at all, from the effects of derailment; to resist which greater strength in the wind bracing will be of no value.

Next.—If there is no tension in the pier columns until 30 lbs. wind pressure is reached, and these columns are properly spliced and anchored, as per specifications, there will be an ample margin of tensile strength in any case where this pressure may be exceeded.

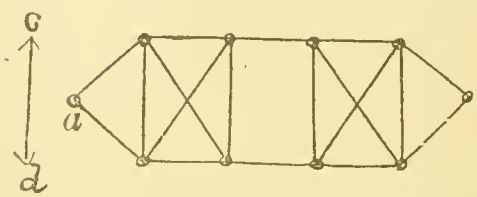
Last.—In view of the comparative rarity of these extreme strains and the consequent slight fatigue to which the iron is exposed, the high stresses imposed on the wind bracing are perfectly legitimate.

It will be noted that the specification as to width of base being such as to eliminate all tensile strains in the pier columns at the specified wind pressure, marks a characteristic difference between European and American practice. The French, Swiss and Austrian viaducts are all exposed to tension in the piers at comparatively low wind pressures, and, although these strains are provided for in the design of each structure, this provision includes subjecting cast-iron to tension, something not permissible in American practice, although our best cast-iron is much superior to that of Europe. Indeed, I am not aware of any skeleton bridge piers in this country which have been built within the last ten years having cast-iron pier columns. Another radical difference is to be found in the structural design of viaduct piers, which in Europe are generally composed of from six to fourteen columns, including two columns as wind braces, one at each end of the pier, while in America the material is concentrated in four or eight columns; the wind braces and load carrying columns being the same. As the internal bracing is or should be strong enough to enable the pier to turn over without collapsing, the great weakness of any pier, which must rotate on a single point, is readily seen from the following sketches:

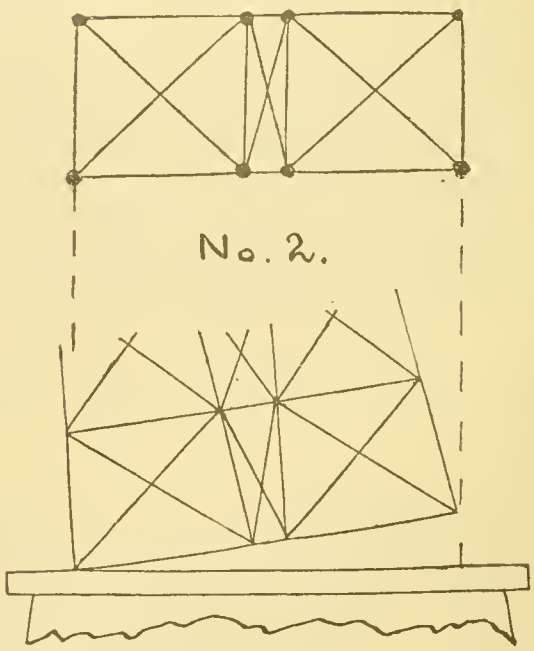
Sketch No. 1 shows the ordinary European ground plan of a skeleton pier, and the position which the pier must assume, if the internal bracing is strong enough to hold the pier together until the overturning pressure is reached. It will be seen at once that collapsing must result from the impossibility of maintaining column "*a*" in the direction "*c d.*"



No. 1.



Sketch No. 2 shows an American pier of the usual type, and the fact that collapsing can be easily guarded against becomes apparent on inspection. It is also evident that unless collapsing is prevented, the full value of the anchorage bolts cannot be obtained. In my enumeration of various railway specifications I have given one from each representative district of the country, excepting New England, and the structures mentioned are, with one exception, located in what is called the "tornado area" of the Western States.



No. 2.

The following account of the St. Charles tornado was written for the *Cosmos*, a local journal of date of March 1st, 1876, by a personal observer, Mr. C. C. Davis, and is published as giving, in the opinion of Mr. C. Shaler Smith, an accurate description of the commencement of the whirl :

At half past one o'clock, on last Sunday afternoon, a heavy storm cloud was observed directly south of the city, moving slowly due north. A few minutes later a similar cloud, but at a greater elevation, and with a much more rapid motion, appeared on the horizon, a few degrees south of west, its course being nearly east. The surface wind at first was light and from the southeast. The clouds soon lapped. Discharges of electricity from the lower to the upper cloud became frequent, but not heavy, and with their junction the entire mass rapidly settled towards the earth. Patches of flying scud appeared moving in every direction, and small showers of rain or hail could be seen falling at various points. The storm nimbus, by this time, had covered all the upper part of the city, its normal cloud tint being here and there flecked with dissolving spots of an unearthly green. Soon came signs of fury which was to follow. The wind came in light fitful gusts from every direction, succeeded by intervals of dead calm, the ominous stillness of the latter being especially marked. After a few short, sharp dashes of hail, interspersed with rain. a most singular phenomenon occurred : a genuine shower of snow balls, some of which, as they lay on the ground, could hardly be covered by a teacup. These were immense hail stones, generated in the cold upper cloud, and softened in passing through the warm and water-laden cloud from the south. So large were they that their white shapes were seen several hundred feet in the air—their color placing them in bold relief againt the murky sullen blackness of their parent cloud. A few moments of oppressive silence followed, when suddenly the rival storm-fiends leaped into infernal life, the ragged wind-scud flew in all directions, and almost instantly the lurid brown of a cyclone column appeared in the southwest, about three miles from the upper end of the city. Moving eastward, at first, until the river slopes had been reached, the terrible cloud column followed them to the city, giving dreadful presage of its coming in a deep-toned humming roar, very similar in sound and disagreeable effect to the noise and earth-shaking, properties of the steam-blower of a locomotive engine, but magnified a hundred-fold. In appearance it was the true cyclone cloud—a brown, murky, vertical,

column, largest at its junction with the parent clouds—never more than 400 feet in diameter—reaching sometimes to the earth, where it destroyed all that it touched; and occasionally receding upwards, and passing harmlessly over those intervening spaces, where its powers were expended in the air above the buildings. Deliberately, but erratically, it moved through our devoted city—death in its roar, and destruction in its touch. The central vortex reached the spire of the German Methodist Church—a twist, a crash, and the spire went spinning upwards, but preserving its vertical position until near the top of its flight, when it was suddenly reversed, and came down point foremost. This vortex also touched the jail, the roof of which, together with the whole upper story, was twisted off—and to this hour the roof has not been found.

From this point the scene beggars all description. The total destruction of everything grasped by the tornado can be compared only to the wide-spread ruin produced by the explosion of a powder magazine. The streets were filled with heavy timbers reduced to the merest splinters. Walls, where not laid flat, were in many cases punctured with holes by flying joists and bricks, projected with a force not much less than if shot from a cannon. Near the vortex houses were destroyed by twisting and bursting; persons inside found it impossible to open the doors to get out, owing to the external vacuum and the pressure from within. On the circumference of the cyclone houses were crushed and overturned by the external force, and those living in this part of its track had doors and windows blown in from without, as a preliminary to the destruction of the building.

After crossing the railroad track, the column became less in diameter, followed a very devious route, and moved so slowly that one observer, who had seen it pass when he was near Morgan street, succeeded in repassing it while it was destroying the houses between Second street and the river in Frenchtown, and reached the bridge sometime before the tornado had finished its work of destruction on the west side of Second street.

After having followed the two main streets of the city to within three hundred feet of the bridge, the cyclone turned suddenly eastward, moved parallel to the bridge, and then crossed it at the middle of span four. It was an anxious moment to the three bridge men who were watching it. The whirlwind had destroyed everything it had touched

thus far, and the deadly column was black with timber and other *debris* of the houses it had wrecked—while high above the rest sailed a large roof, moving with terrific speed towards the bridge, which it was now clear would be crossed by the very vortex of the storm. For a second the cloud obscured the span, the flying roof soaring fifty feet above it, but in another instant the grand old bridge loomed out clear and sharp—its outlines all unbroken against the black background of the defeated Storm-King who swept muttering away.

From the bridge the column crossed to the St. Louis shore of the river, destroyed a number of large trees on that side and then turned and crossed to the west side again, raising the water nearly 200 feet high in its path, and reaching the St. Charles shore some two miles below the bridge. From this point it ceased to be a St. Charles institution and we must rely on our country correspondents to tell us of its doings beyond our immediate ken.

At 15 minutes past two the storm was over, and half an hour later the sun was shining, and the uncomfortable warmth of the morning had given place to a cold and chill atmosphere and western wind, which followed in the track of the higher and colder cloud, and which, in this battle of the elements, has proved victorious.

From the circular motion of the wind, it is difficult to measure its exact force, although there are several definite points where we are enabled to fix positively that the pressure exceeded a certain limit. One of these is the water tank at the jail. This stood fairly where the wind could act both on the sides and bottom. With the water in it at the time, we are told that $69\frac{2}{10}$ pounds per square foot upward and lateral force was required to over turn it, and it *was* overturned.

Another point fixed is the overturning force required to carry off a barrel half full of coal tar which stood on the bridge, and which was blown over and away. This needed $71\frac{5}{10}$ pounds pressure to overturn it. The significance of these figures will be understood when we state that a wind, with a speed of 80 miles per hour—giving a pressure of $31\frac{1}{2}$ pounds per square foot, is defined by the authorities as a "violent tornado." We are perfectly satisfied with our experience in cyclones and want no more of them.

DISCUSSIONS ON THE PAPER UPON WIND PRESSURE UPON BRIDGES.

Charles Douglas Fox, of London, Corresponding Member A. S. C. E.—Mr. C. Shaler Smith's paper is to me very interesting as being the first instance I have seen of an attempt to formulate distinct rules upon this subject. It is understood that the French engineers adopt a maximum wind pressure of 55 pounds, but in Great Britain the matter has been hitherto left to the discretion of individual engineers, the Board of Trade requirements for railways making no mention of the point.

It is but comparatively rarely in English practice that bridges occur of such span and height as to render necessary any separate consideration of the wind pressure upon either girders or piers, the strength and stability necessary to resist the effects of trains running at high speed, with a factor of safety of 4, being, in ordinary cases, such as to provide a large margin for safety against the effects of wind. A perusal of the evidence given before the commissioners appointed to report upon the accident to the Tay Bridge will show that engineers and scientists also widely differ as to the pressure to be expected, both as to their force and their extent, ranging upon the structure in question, having spans of 245 feet, and a height of 115 feet, from 15 pounds up to 50 pounds per foot. The Astronomer Royal of England stated, in his evidence, his opinion, that, whilst a force of 40 or 50 pounds per superficial foot might be experienced upon limited areas, say up to 250 feet in width, the maximum average force upon a larger area of say 1 600 feet in width would, probably, not exceed 10 pounds per superficial foot, but this would, from Mr. Smith's paper, appear to be contrary to experience in the United States at least. It was further stated by engineering witnesses, that, leaving out of consideration the strength of the bolts which secured the cast-iron columns to the piers, it would have required a force of from 33 to 34½ pounds per foot, or, taking the bolts into account, then from 60 to 70 pounds per foot upon the piers, girders, and a train of carriages to overturn the bridge, if no failure took place in the details of construction. At the time of this inquiry, in the spring of 1880, no reliable measurements of pressure up to 50 pounds per foot had been made at the Royal Observatory, but I understand that, in the terrific easterly gale of Janury 18th last, the anemometer, on three occasions, registered

this amount of pressure. As, however, the instrument is placed on the Observatory Building, it is possible that it may be subjected to eddies, which would cause it to register more than the normal pressure.

My practice, which I believe, accords with that of many engineers in this country, has been, in dealing with roofs, to assume a maximum pressure per superficial foot of 40 pounds, of which 30 pounds are taken for the resultant pressure of the wind, at right angles to the roof, and 10 pounds for snow, it being very rare for much snow to lie upon such structures, when there is a heavy wind. For India, where our structures are exposed to severe cyclones, the same maximum pressure of 40 pounds is taken, in this case wholly for the wind, snow being unknown. The maximum strain upon the wrought iron of the roofs under such pressure would be about 16 000 pounds per sectional inch, giving a factor of safety of at least 3. Roofs thus proportioned have been lately exposed, without injury, to one of the heaviest cyclones ever known in South India, a storm which tore up trees by the root, and caused very serious damage to buildings of various kinds.

Robert E. Johnston, of Liverpool, M. I. C. E.—The question of wind pressure does not appear to have received the amount of attention from British engineers that the importance of the subject demands; this, no doubt, is due in a great measure to the fact that the wind in this country does not attain to anything like the force it does in America, but the destruction of the Tay Bridge has given a prominence to the subject it never had before, and has proved that even in this country the effects of the wind cannot, with impunity, be neglected. The extent of our information of a reliable character with regard to the pressure of the wind and the force it exerts against the complicated forms which the varied structures erected by engineers assume, is of a very limited nature, and it is desirable to determine by actual observation the pressure exerted by the wind at various velocities on flat, inclined, hollow and round surfaces. Investigation should also be made as to the action of the wind on close latticing, and the reduction that takes place in the pressure on the rear surface when two flat surfaces are immediately behind eath other, and at varying distances apart. Information of this nature would enable the floor and over-head bracing of open web girders to be determined with more precision than at present. It is usual to allow of a reduction of one-half as between the pressure on

the windward and leeward girders in this country, and, I think, a similar practice is followed in America, but there appears to be no reliable ground for this assumption.

I think the pressures Mr. Smith instances as having destroyed buildings must have been greater than he gives them, as I presume they were deducted from the moment of stability of those structures, which would not take into account the reduction in velocity from friction in passing over the ground. In my own practice, when determining the strains on roofs and other structures affected by the wind, I take the wind as exerting, in a horizontal direction, a pressure of 30 pounds per square foot, and I think this agrees with that adopted generally by English engineers.

In my opinion it must be admitted that the ground plan of a metallic skeleton pier, which is a parallelogram, is the one best suited to resist the strains, both vertical and lateral, to which it is exposed, and that the columns should be placed at its four corners in preference to the complicated grouping of the columns, as illustrated by the Crumlin and Fribourg Viaducts. The question of whether the base of the pier should be spread out so as to have no tension strains at that point appears to me to be one largely governed by the question of cost and local circumstances, for if a pier is to be placed in a navigable channel, or in deep water, it is desirable to keep down the dimensions of the coffer-dam or caisson to the lowest possible limit.

Under these conditions it would appear to be sound engineering to reduce the base of the pier and resist the tension of the iron portion by anchoring it down to the mason work, but when the masonry foundations can be provided without undue expense, the base should be enlarged so as to be stable without holding down bolts, in the manner adopted by Mr. Smith in his remarkable bridge over the Kentucky River, and almost to the same extent by M. Nordling, in his Viaducts on the Commentry & Gannat Railway, in France, where, at La Double, and other bridges erected by him at the same period, the total tension on the holding down bolts is reduced to about 20 tons by the spreading out of the base in a lateral direction. The piers of the Kentucky Bridge are mounted on rollers both in the longitudinal and transverse direction, and it would be interesting to know to what extent movement has taken place from expansion and contraction at the foot of the piers.

The highest pressures registered in Great Britain are those recorded

by Mr. Hartnup, at the Observatory at Bidston, and through the courtesy of that gentleman I am able to give the following particulars of the great storms of wind that have passed over that place between the years 1868–79 :

Date of Observation.	Greatest Velocity in Miles between any hour and the next hour following.	Greatest Pressure in Pounds on the Square Foot.	Direction of Wind.
27th December, 1868.....	92	80	W.
13th October, 1870.....	82	65	W. S. W.
9th March, 1871.....	79	90	W.
27th September, 1875.....	81	70	W. S. W.
23d November, 1877.....	80	64	W.
28th December, 1879.....	59	38	S. W.

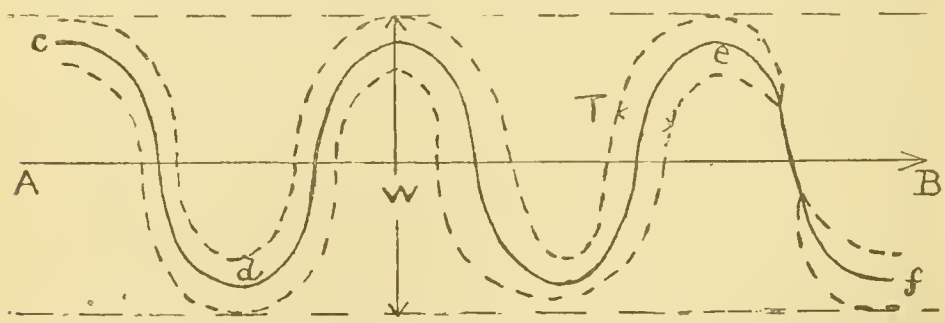
The velocities were registered by Robinson's anemometer, and the pressures by Osler's anemometer. For the last 30 years I have resided within a couple of miles of the observatory and am well acquainted with its surroundings, and having regard to the high pressures recorded, I think they can only be regarded as having been of momentary duration and of an entirely local character, for if the storms that gave rise to them had partaken of the cyclonic character of those enumerated by Mr. Smith, the houses in the neighborhood of the observatory must inevitably have been blown down, and no such a calamity has occurred in the district during the period I have mentioned, which is the strongest testimony that can be adduced in support of my opinion. If further evidence were required, I might state that I have been connected with a railway, that has its terminus about three miles from Bidston, for the last 25 years, and during this period no cars or freight trucks have been blown over, and as these have a stability of from 30 to 40 pounds per square foot, they cannot have been exposed to gales of wind with pressures ranging as high as 90 pounds per square foot. It may be of interest for the Society to know that Bidston, where the greatest wind pressures have been registered in this country is three miles from Liverpool on the Cheshire side of the Mersey and two miles from the Irish

Sea, standing on an eminence about 200 feet above sea level, being at the same time exposed to the full force of the wind from all quarters of the compass.

G. Bouscaren, M. A. S. C. E.—I wish to preface these remarks with thanks to Mr. Smith for his very valuable contribution on a most interesting subject, in regard to which so little is known by the best informed.

The author has, I believe, stated correctly in his paper what American engineers' practice in regard to wind strain on bridges has been in the past ten years. The question to elucidate in this discussion is, whether this practice is sufficiently safe, when considered in the light of present knowledge on the subject of wind power, and in the face of changes now being introduced in the rolling stock and machinery of American railways.

First.—It seems that the information given, concerning tornados in particular does not warrant the positive assumption, that their width of area of maximum effort is less than the ordinary limits of bridge spans. From my own observations, the general movements of a tornado seem to be of four kinds.



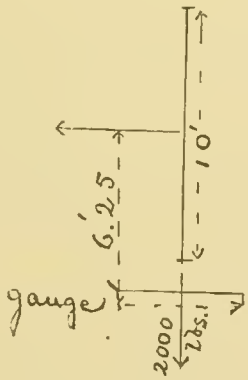
1st. The gyratory motion on its axis. 2d. The advance onward in the general direction, *A B*. 3d. An irregular oscillation to the right and left of the general direction, causing the axis of the vortex to describe a sinuous track, *c, d, e, f*, which, as stated by Mr. Smith, gives an apparent breadth of swath, *W*, much larger than the width, *T*, of the actual track.

4th. An irregular vertical oscillation, causing the width, *T*, which measures the diameter of the vortex to vary constantly, and to such extent as often to disappear altogether, the tornado jumping up, as it were, for a time, and leaving unharmed for a certain distance directly in its course, objects of comparatively little resistance. If I am correct,

the small observed width of the St. Charles tornado may be very reasonably explained by the supposition that the cone was well up in its vertical course when it struck the bridge. The margin between the pressure assumed in our calculations, and the highest pressure on record deduced from actual failures of structures, seems sufficient, but there is, nevertheless, reasonable room for doubt, which can only be dispelled by numerous and well directed observations.

The knowledge of the relations which the pressure of the wind bears to its velocity, and to the shape of surfaces exposed are important factors in the problem, but the great desiderata are accurate measurements giving the greatest effort actually exerted by the wind on the largest area.

Second. Mr. Smith makes the pressure per square foot necessary to upset a fully loaded freight train 56½ pounds, this can scarcely apply to prevailing railway practice at the present time. Box cars being now made to carry twenty tons and over, it would not be safe to reckon on a train load of less than one ton per lineal foot behind the engine. This



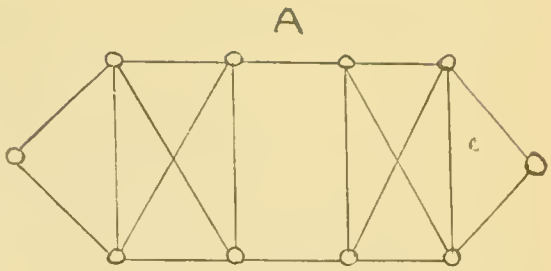
with an exposed surface of ten feet, and a height of 6¼ feet from centre of pressure to top of rail, which are maximum figures, gives for the upsetting pressure per square foot, 80 pounds for five feet gauge, and 75 pounds for 4′ 9″ gauge. Now, it is true, that a train would not run under a wind approximating such a force, for the tractive power of the locomotive could not overcome the train resistance with the additional friction of the wheel flanges against the rails, but the sudden apparition of a tornado, surprising a train moving or standing on a bridge or viaduct, makes it quite *possible* that the structure be subjected, with a train on it, to a pressure approaching 75 pounds per square foot, should the wind reach such a pressure. At all events, one conclusion is very clear

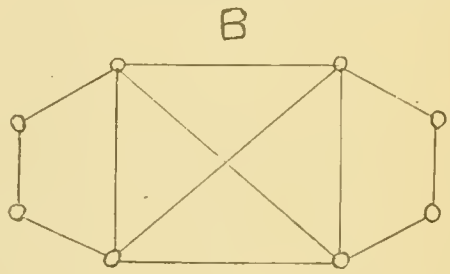
to me. We *know* positively that empty cars may be upset by the wind; this eventuality should be met with sufficient provision to resist it, in the design of bridges and viaducts.

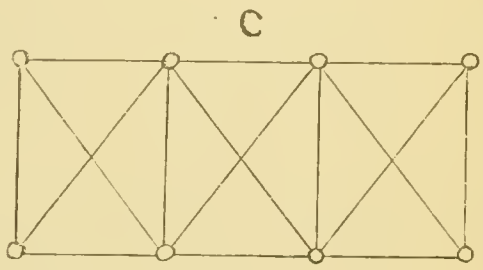
Third.—It is undeniable that the rule of *no tension* in the columns of piers, with a good anchorage as an additional safeguard, is all that could be desired with reference to safety; but I do not think that it should be made absolute; in extreme cases it might involve a large additional outlay for masonry. With wrought iron columns well spliced, I do not see the objection of utilizing the masonry (with a large additional excess of weight) to resist the tension due to wind storms of exceptional force. Where cost can be reduced without sacrificing safety, it is not only legitimate but imperative to good engineering to do so.

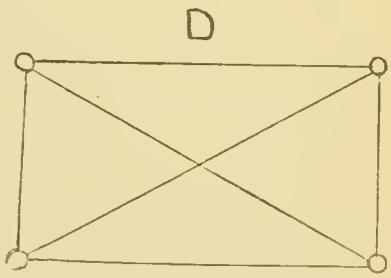
Fourth.—In regard to the maximum strain per square inch allowable under wind pressure, my practice has been 15 000 pounds in tensile members, and as given by Mr. Smith for other parts, being equivalent to an addition of fifty per cent. to the maximum strains under the normal load. I have now come to the conclusion that this is too much, and in the future will only allow 12 500 pounds per square inch in tension. My reason for doing this is that the strains arrived at by calculation suppose that the force of wind is applied gradually; the strains due to the same wind, if applied suddenly (as would happen to a more or less extent in the case of a tornado), might be doubled in value, and reach 30 000 pounds per square inch, which is beyond the limit of elasticity of ordinary bridge iron.

In conclusion, I beg leave to put in a few words in behalf of our European brothers. It is but proper to say that the ground plan of Skeleton pier *A* given by Mr. Smith, as representative of the European type, is far from being generally used on the Continent. I do not know of a single case in France. Of the six French viaducts described by M. Nordling in his work, three are of the type *B* and three of the type *C*, of which is also the viaduct at Fribourg, in Switzerland, built by a French firm.









It is true that the piers of those structures are of cast-iron, but it must be remembered that they were all designed prior to 1864, at which time the use of cast-iron in columns was universal. This practice is now abandoned, at least by French engineers.

The bridge over the Douro, erected in 1877, by M. G. Eiffel, and the Garabit viaduct now being built by the same engineer for the Marvejols and Neussargues Railway are good examples of the present practice.

The piers in both structures are of the type *D;* the columns are of wrought-iron ; they are rectangular in section ; closed in the Douro plan, and open, with lattice work on one side, in the Garabit plan.

The practice, in regard to wind strain, is to assume a pressure of wind of 35½ pounds per square foot on the structure with a train on, 64 pounds per square foot on the structure without a train on, and take the highest results. The maximum normal strain allowed, which is about 8 500 pounds per square inch in tension, includes the strain due to the wind, which is often a considerable portion thereof. In the Garabit viaduct, for instance, the strain per square inch on different members of the 540 feet arch divides very approximately as follows :

	Strains per Square Inch in Pounds.			
	Due to Dead Weight.	Due to Rolling Load.	Due to Wind.	Total.
On the chords of 540′ arch.	2 833	2 833	2 833	8 500
On the web " "	1 400	1 400	4 200	7 000

Willard S. Pope, M. A. S. C. E.—The paper by Mr. C. Shaler Smith is a valuable addition to the stock of information on effects of wind. The provisions as to construction of bridges which his specifications call for, accord, I think, with the best practice of American bridge engineers of the present day. A structure designed and fairly built in accordance therewith will, doubtless, be safe as against the *lateral* pressure developed by any wind. But there is also a *vertical* tendency to be provided for. The effects of a whirlwind may be not only lateral, but also, under certain conditions, upward. Every one has noticed how the little eddies pick up dust and straws in the streets. I have seen on the plains of Wyoming and Colorado columns of dust, doubtless 200 feet high, with distinct and sharply defined outlines moving majestically over the ground, held within the vortex of a whirlwind. Ocean navigators tell of vast masses of water, weighing hundreds of tons, thus lifted up into the air, like great vertical pillars.

The mere upward spiral whirl of the disturbed air is probably insufficient to develop this tremendous vertical energy. It may, perhaps, be supposed that the central core of the tornado is a vacuum, more or less complete, formed and sustained, possibly, by the centrifugal power of the gyrating particles of air; and as the open base of this cylindrical, vertical, vacuous column trails along the surface of the earth, movable matter, exposed to its influence, rushes upward into it with a velocity and momentum due to atmospheric pressure as well as to direct force of wind. Roofs of buildings are frequently lifted off, although the only exposure to actual upward wind pressure is at the projecting eaves and cornices. But suppose this vacuous column passing over the building; with what explosive force the confined air within would shoot the roof upward, and the walls outward.

The existence of this vacuum seems essential to explain some of the

phenomena connected with tornadoes ; and if such vacuum really occurs, it must develop a tremendous force vertically, just as the wind itself develops a force horizontally.

That such upward force may destroy a bridge I have some evidence. About 1858 a railroad, of which I was engineer, lost a bridge by wind. It was a wooden, through Howe truss, in two spans of about 100 feet each, with the chords framed together over the central pier. The bridge was not roofed or covered. The location was such that the structure was well sheltered by timber, and from the underside of the bridge to the surface of water in the stream was only about 15 feet.

The direction of the bridge line was east and west, and the storm passed from north to south.

When I reached the scene of the disaster, a few hours after it had happened, I found the spans in the river, badly wrecked, of course, but still continuous, and in tolerably fair line. The west end laid at the base of the west abutment, the central part just cleared the southerly end of the pier, while the east end laid probably about 20 feet southerly from the east abutment. The bolsters underneath the ends of the lower chords had been, when built, shouldered about two inches into transverse wall-plates of oak. These wall-plates (which had not been bolted to the masonry) were still lying in their places on both the east abutment and the pier, while those of the west abutment had been dragged into the river. If the spans had been tipped over, or had been slid off the masonry, by the horizontal force of the wind, they would certainly have taken the wall-plates with them. On the east abutment there was no sign of a blow from falling timber. There happened to be a joint in the track rails on the bridge within three or four feet from the east end. The ends of the bank rails were still protruding out over the edge of the abutment, and the ties attached to them had evidently been raised vertically from their beds in the embankment.

If the east end of the bridge had been lifted up bodily, and thereupon been moved 25 feet or so southerly, turning on the west abutment as on a pivot, and then dropped into the river, all these appearances would have been accounted for. I could make no other hypothesis that would explain them.

To lift this bridge required an upward pressure of about 80 pounds per square foot of exposed surface. This is on the supposition that the floor system was bolted to the trusses, which was the fact.

Applying this to a modern iron bridge of, say, 160 feet span : the horizontal surface of the iron work only is, say, 9 square feet per lineal foot of bridge. An upward pressure of 80 pounds per square foot would amount to 720 pounds per lineal foot. And as the iron work will weigh, say, 1 100 pounds per lineal foot, the structure will be safe. But the flooring thereon (for a railroad bridge) exposes, say, 11 square feet of horizontal area per lineal foot. This, at 80 pounds per square foot, amounts to 880 pounds per lineal foot, to counterbalance which is only about 300 pounds of dead weight of flooring. The upward pressure, therefore, on the two combined will be, say, 1 600 pounds, while the total resisting weight will be but 1 400 pounds.

The moral is, do not bolt the flooring firmly to the trusses.

If this reasoning is correct for railroad bridges, much more does it apply to highway bridges, where the area of flooring is generally much greater proportionately.

Joseph M. Wilson, M. A. S. C. E.—Mr. C. Shaler Smith's interesting paper on Wind Pressure seems to pretty well cover the subject, so far as present information on the matter allows, and agrees essentially with my own practice, except that in taking wind pressure at 30 pounds per square foot on vertical bridge surface with that on train at 300 pounds per foot lineal. I have been in the habit of taking only one truss, and have usually not exceeded the ordinary limits of working stress, such as 10 000 pounds per square inch tension on wrought iron, &c., &c., and also have not taken the pressure on the train as a moving load. I fully agree with Mr. Smith as to the propriety of taking this as a moving load, and also as to increasing the limiting stress ; but in doing so, I should, as he does, take twice the vertical surface of one truss, and should be inclined to make my pressure 40 pounds, instead of 30, in very exposed localities.

The addition of an initial stress to allow for strains produced in screwing up the rods is a good point.

In some of our exposed buildings we have taken 25 pounds per square foot of surface on one side with no increase in working stress over ordinary limits, but in later work have adopted 30 pounds, with an increase in allowable stress of about one-third.

I should be glad to see some more reliable observations made on the matter of wind pressures at a point where high velocities are attained, Mount Washington, for instance, the question of surfaces of different

forms being considered, such as concave, convex, and those given by I beams, channels, &c. Also the loss of effect caused by the wind passing through the openings of one truss on to another, &c.

While I agree, of course, with Mr. Smith that the American form of trestle is decidedly preferable to the European form, still I think his criticism on the latter is a little severe, as the column *a* must be prevented from collapsing in the direction *c d*, at least to a great extent, by the bracing connecting it with the two adjacent columns of the trestle, and forming a triangle in horizontal section if such bracing is made heavy enough.

A. Gottlieb, M. A. S. C. E.—The views of Mr. C. Shaler Smith, with reference to wind forces and wind strains, as stated in his paper, meet my own views in every respect.

I believe that a wind pressure of 30 pounds per square foot on the side of a train, as also on the whole surface of the windward and such portions of the leeward truss, as may not be moved by the train, is sufficient for the safety of structures.

I have no doubt that winds of greater force than this occur, but considering that they are very exceptional, and as Mr. Smith states, their paths are narrow when they occur, I do not think it necessary to provide against larger wind forces than 30 pounds per square foot, certainly not for spans over 200 feet.

One point, I believe, however, Mr. Smith has not treated as fully as its importance calls for.

Every one of us has seen structures and bridges erected, with parts proportioned correctly to resist specified live as well as dead loads, as far as the sections of the members were concerned, and still the structures were failures, owing to defective details in the connections. So it is also with the members intended to resist and to transmit wind strains, and I might say in still a higher degree.

Engineers generally pay too little attention to this most important fact, and the consequences are twisted struts, bent pins and distorted chords ; although the sections of these members, intended in the first place to resist wind strains, may even have been excessive.

In connection with this I will state, that I think it advisable that the sections of bottom chords of spans over 200 feet should be increased to resist the horizontal strains from wind strains.

The usual practice is to provide for the strains arising from live and

dead loads only in bottom chords, disregarding entirely the additional tensile strain, which is brought to act on one line of chord from the lateral rods.

I find that with the usual live load of two locomotives followed by cars and a wind force of 30 pounds per square foot, the additional stress in one line of bottom chord produced by the lateral rods over and above the strains derived from live and dead load combined, is for—

Spans of	100 feet,	about	25 per cent.
"	200 "	"	40 "
"	400 "	"	50 to 60 per cent.

Taking the working strain in members of wind bearings and their connections 50 per cent. larger than for the vertical loads, the increase of section required in bottom and chords would be—

For	100 feet	spans,	16 per cent.	Over and above the section usually given.
"	200 "	"	26 "	
"	400 "	"	33 to 35 per cent,	

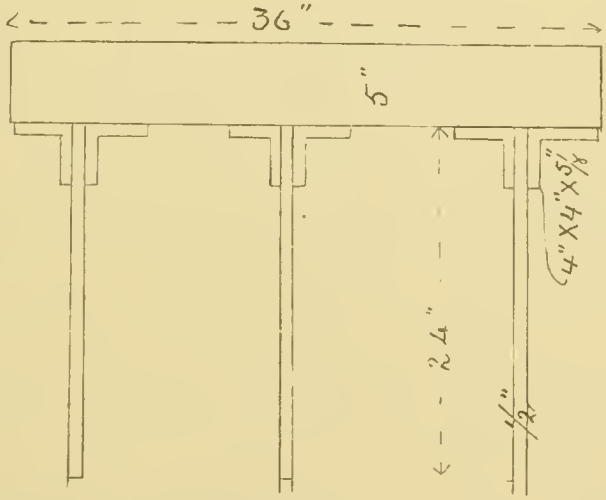
I believe that in all spans in which the section of bottom chords, required to resist wind strains, should exceed the section provided for live and dead loads by 25 per cent or more, this additional section should be given the chords, particularly as it could easily be done without increasing the dead weight of the structures materially.

The Chicago & Alton Railroad has lately adopted the rule to increase the section of every member of the bridge on account of wind strains, even floor beams, track stringers, top chords and posts. I believe this unnecessary, and rather detrimental to the structures, as it increases their dead weight, without adequate benefit to compensate for it.

D. J. Whittemore, M. A. S. C. E.—This paper will have done excellent service aside from that due to its merit, if it will cause others to contribute such facts as to extent and ultimate concentrated force of tornadoes, as may come clearly and definitely within their knowledge. It appears to me that the same practice in designing structures to resist wind strains should prevail outside of the present known tornado belt that should be employed within it. Some eighteen or twenty years ago a tornado swept over and destroyed the village of Viroqua, Wisconsin, and in the supposed path of greatest effect carried wheat straw with sufficient velocity to cause it to penetrate through the one-half inch pine sideing of a destroyed dwelling house, and the piece of board with the

straws sticking through it is now in existence at the place mentioned. Who has the data from which to calculate the force required to cause this effect ?

While our bridge experts generally conform to about the specifications set forth in Mr. Smith's paper there are many designers and builders of structures who do not—some in this country and some abroad. I would call members attention to a recent volume of the Proceedings of the Institution of Civil Engineers (Vol. LXI., p. 190), which contains a description of a viaduct built across the Clyde, at Glasgow, in 1878, which clearly shows the difference between English and American practice in regard to wind bracing. The viaduct carries four tracks and consists of five spans ; each span has two riveted lattice trusses placed 50′ 0″ apart centre to centre, plate floor beams at the panel points, riveted stringers under each rail and a floor covered with Mallets buckle plates. The longest span is the part of the work I chiefly wish to refer to ; its trusses are 199′ 0″ long, twenty feet in depth, and the floor beams apparently rest on and are riveted to their bottom chords. The panel length is 10′ 0″. Both top and bottom chords are built up of plates and angles as sketched, and the iron in them is strained to four tons (8 960) per square inch by the calculated loads both in compression and tension.



The description of the top lateral bracing is as follows (p. 197): "The tops of the girders over the river are connected by cross bracing 20′ 0″ apart. These braces are light lattice girders having the upper boom fish bellied. They assist to stiffen the viaduct, but the object for which they were erected was to support smoke boards, which were

erected, at the instance of the Clyde Trustees, to prevent sparks flying on to the shipping below."

From this we would infer that the writer of the paper thought that this span did not require any top lateral system as he states that the cross bracing was put in to carry smoke boards. Without lateral bracing the top chord would be a column of over 60 diameters strained to nearly 9 000 pounds per square inch, and the stability of the trusses would chiefly depend on their connection with the floor beams which are only 16¾" deep at the ends where they are riveted to the bottom chord.

It is impossible to estimate the stiffness which this arrangement gives to the structure without seeing the exact detail of the joint, and this is not given in this paper. But there can be little doubt that strong top lateral and portal bracing would greatly increase the strength and durability of the bridge.

A. S. C. Wurtele, M. A. S. C. E.—I have read with interest the advance copy of paper by C. Shaler Smith, on Wind Pressure on Bridges, and consider it a full statement of a subject which has not received sufficient attention ; my experience, from examination of plans as consulting engineer, being that the additional strain in chord members, due to wind pressure, is quite neglected.

I know of no definite results as to the effect of such pressure on open lattice work, but do not think it equal to the actual surface, for whilst lowering a 60 lb. span lately, during a high wind, I found the guy lines only slightly strained, the support being only two long jacks at each end.

From the double bearing the calculation of swing strains is indefinite and comes under the class of imperfectly fixed trusses, so that a complete reduction would give rather a fanciful result ; but it is best to assume the worst condition of one side only fixed.

I prefer to use the same specified strain as for a load with a lesser wind intensity, so as to get sections of combined strain at one operation —at 20 pounds pressure would equal 50 pounds before elastic limit would be reached under load strains.

Chas. A. Smith, M. A. S. C. E.—I have observed when standing upon high bridges and other exposed situations, that very frequently the wind came in regularly recurring periods or pulsations. In three instances at St. Charles, and one at Plattsmouth, the interval between pulsation was about one second. These were not the irregular gusts which, of course, occurred, but continued for hours. It is possible that such

action of the wind could produce oscillations in the structure itself, if the periods agreed with that of lateral vibration, or if one was a multiple of the other.

Concerning the values used it would appear that the pressure recommended by Theodore G. Ellis, M. A. S. C. E.,* and adopted by F. Slataper, M. A. S. C. E., would be preferable to members of the community who are not manufacturers of bridges, and also would give a better margin for the effects of vibration and that unknown element, viz. ; the lateral force required to keep a long compression chord in line which is theoretically nothing if the chord is in line, and which increases with the allowable deviation. If the 30 lbs. allowed be enough for the wind, does it include this effect or not, and will not the higher value of 40 lbs. give a structure with less lateral vibration ? The amount of metal in question is not very great, and the life of the bridge must be increased thereby.

Robert Fletcher, Asso. A. S. C. E.—Confessedly our knowledge concerning this subject is imperfect, and we have scarcely any data or formulæ upon which we can confidently rely. The mistake of attempting to deduce conclusions as to the actual pressure of strong winds upon large stationary objects from the velocity of rotation of the arms of an anemometer, is admitted. The probability,—we may almost say certainty,—that the intensity of pressure on the exposed surfaces of high structures increases from below upwards, throwing the centre of pressure above the centre of figure, has been referred to by J. B. Eads, M. A. S. C. E., in a former discussion,† and also by J. B. Francis, M. A. S. C. E., in his valuable report on the stability of the chimney of the Lawrence Manufacturing Company.‡ If there is any law for this increase, it must be dependent upon special and perhaps obscure conditions in each case, and it would not be an easy task to determine it. The influence of the size and form of the resisting object and of the partial vacuum shown by the eddy have also been noticed in the previous discussion. The latter condition is one of great importance.

Weisbach shows that for the pressure of moving water against an obstruction we may write, theoretically,

$$P' = Fhj + C' \frac{v^2}{2g} Fj,$$

*See Transactions, A. S. C. E., Vol. IV, page 132, May 1875.

† Transactions, Vol. IX, p. 395.

‡ See Engineering News, Aug. 28, 1880.

(Mechanics of Engineering, Vol. 1, p. 1030) in which F is the surface pressed, h the hydrostatic head, j the heaviness of the water, — therefore Fhj is the hydrostatic pressure, — v the velocity of impulse, C' an empirical co-efficient dependent upon the shape of the surface and, therefore, the second term expresses the pressure due to impact. Similarly against the back surface, where the eddy occurs, the expression is $P'' = Fhj - C''\frac{v^2}{2g}Fj$, in which C'' is an empirical co-efficient for this case. Hence for the resulting impulse we have

$$P' - P'' = P = (C' + C'')\frac{v^2}{2g}Fj.$$

He then says: "This general formula for the impulse and resistance of an unlimited stream is also applicable to the impulse of wind and to the resistance of air. Here, however, besides the difference of the ærodynamic pressures upon the front and rear surfaces, a difference in the ærostatic pressure also exists, which is due to the fact that the air at the front surface has a greater heaviness (j) in consequence of its greater tension, than that at the rear surface." Another remark is of importance in this connection: " * * * a certain quantity of air or water attaches itself to the body, the influence of which is shown by the variable motion of the body, which, *e. g.*, is very evident in the oscillations of a pendulum. The quantity of air or water which attaches itself to a sphere is 0.6 the volume of the sphere. For a prismatic body, moving in the direction of its axis, the ratio of these volumes is

$$0.13 + 0.705\frac{\sqrt{F}}{e}$$

in which e denotes the length and F the cross-section of the body. This ratio, which was first determined by Du Buat, has been fully confirmed by the later experiments of Bessel, Sabine and Bailly." For the impulse of air and water upon a plane surface, the experiments of Du Buat and also of Thibault give $C' + C''$, or, more simply, $C = 1.86$, about two-thirds of the action being upon the front, and about one-third upon the rear surface. This was for a uniform velocity of impact. Ashbel Welsh, M.A.S.C.E., in commenting* upon the experiments of Beaufoy on the resistance to prismatic bodies moving through water, infers that in air this co-efficient would be greater than Beaufoy's value which was 2.3. But the results obtained by Du Buat, Duchemin, Newton, Borda,

* Transactions, Vol. IX, p. 392.

Hutton and others, as cited by Weisbach, for prisms and spheres in water and air, at moderate and high velocities, show no values as great as 1.5.

After all that has been done we are still left in doubt. Previous experiments generally were made on too small a scale, or under conditions otherwise not according with those with which the engineer has to deal. Hutton has given us an empirical formula which involves the inclination of the exposed (plane) surface to the direction of the wind. It is especially applicable to roofs,* but requires us to assume a certain arbitrary intensity of horizontal wind pressure.

It is evident, then, that while theories and formulas based upon previous experiments and observations by distinguished professional men are valuable, nevertheless, we must put these in the background, and call for actual facts and data derived from careful and close observation, under conditions, usual or possible, of our practice at the present day. The paper of Mr. C. Shaler Smith is a valuable contribution, and goes far towards meeting this demand. We need a great deal more of the same kind of information, and then a thorough comparison and digest of the results embodied in the form of practical rules. But, of course, in applying results of such observations to a particular case, great care must be taken to see that the conditions correspond as nearly as possible to those occurring in connection with the results to be made use of.

I have had in view for several years past the making of systematic experiments on wind pressure, but have not yet found either time or means or suitable facilities at hand. And, indeed, no one person can generally command the means and access to all the localities necessary for the proper prosecution of such a work. Necessarily, there must be co-operation and separate experiments by a number of engineers, according to some carefully prearranged plan. I would offer the following general suggestions for such a series, leaving detail and additions to be suggested by more experienced members :

1st. A sufficient number of self-registering dynamometers should be provided for use at different points for direct and simultaneous measurement of the pressures, somewhat after the method pursued by Thomas Stevenson in his measurements of the force of the waves,† but on a

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* See Greene's "Graphical Analysis of Roof Trusses," Chapter VI.

† See Stevenson's "Design and Construction of Harbors," Chapter IV.

much larger scale. Different series would have to be conducted for different classes of structures, as follows :

2d. Surfaces high, broad, and substantially plane, as the faces of large, high buildings, observations so as to show the variation of pressure from below upwards, and both on the windward and leeward faces. The mechanism of self-registering need not be made to operate for a long time, if the instruments could be set at the beginning of a storm, and watched. In this connection, I think it would be important to observe the amount of partial vacuum at one or more points of the leeward face, which might be done with aneroid barometers.

3d. Surfaces high, narrow, and substantially unbroken, as high masonry towers, chimneys, high piers, etc., observations similar to those just described. In these cases the eddy or partial vacuum on leeward side is probably more, relatively, than in case of large buildings. The great importance of this effect may be inferred from the remarks of Robert Briggs,* M. A. S. C. E., in the former discussion, and by considering that a variation of half an inch only in the barometric pressure before and behind, means a preponderance of ærostatic pressure amounting to about ¼ pound per square inch = to 36 pounds per square foot, which is in excess of pressure due to the impact alone from a very high wind. Mr. C. Shaler Smith bears testimony to the influence of this partial vacuum in stating that nearly all the buildings he has examined in the tracks of western tornadoes appear to have blown outwards. Many will remember the curious illustration of this principle shown at the Philadelphia Exposition,† where a ball of considerable weight was sustained on the *lower* edge of a jet of air from an air-compressor, said jet having an inclination of 60 degrees to the horizontal. The partial vacuum on the leeward side of the ball, caused by the jet above the ball and a small part which passed underneath, made a preponderance of ærostatic pressure acting upwards, and the resultant of this and of the force of impact was sufficient to counteract the weight.

4th. Similar observations on framed structures, as trusses and trussed towers and piers, both near the surface of the earth, and in specially high and exposed situations. In these cases it would be interesting and important to learn more certainly than we now know, the shielding effect of one part of the structure upon those parts not receiving the first impact of

* Transactions, Vol. IX, p. 398.

† See *Scientific American* Supplement, Vol. II. p. 736.

the wind. Also the amount and influence of the contraction of the stream of moving air as it passes between the parts of the truss. Probably in many structures, or behind certain parts of large frames and trusses, a very considerable degree of exhaustion of air would be observed.

5th. In some cases, during brief intervals, with enough observers working together, aneroid barometers simply might suffice to measure approximately, if not, indeed, as accurately as some other apparatus, the pressures on windward and leeward faces of structures or parts of structures.

Such a series of experiments would show the influence of height above the earth's surface, the form and size of the surface or combination of surfaces, the effect of inclination to direction of the wind, and of other conditions which would be suggested.

Manifestly, it would be necessary to have simultaneous observations of velocity, and some means of noticing the exact direction of the wind, so far as practicable.

O. Chanute, M. A. S. C. E.—I have heard some members ask, why if he has observed a wind pressure of 93 pounds per square foot, Mr. Smith still thinks it safe to proportion his structures for 30 pounds per square foot. They urge that in the course of years, at some time or another, those extreme pressures will be realized.

I apprehend that they have not clearly understood Mr. Smith's argument. Not only, as he states, are those extreme pressures limited to very narrow belts—less than the length of ordinary spans ; not only would a train be blown over by a far less pressure, but it is most unlikely that a train would venture across a bridge during the prevalence of such a tornado.

In that case the exposed area, instead of being 21⅓ square feet per foot lineal, for train and trusses, would be 11⅓ square feet, for the latter alone. Upon this a pressure of 90 pounds per square foot would amount to 1020 pounds per lineal foot, instead of the 640 pounds per lineal foot (estimated at 30 pounds to the square foot), upon the bridge and train; so that if the latter strains the wind bracing 15,000 pounds to the square inch, the tornado will strain it 24,000 pounds to the square inch; which, as Mr. Smith says, is still within the limit of elasticity.

There are one or two additional considerations which Mr. Smith might have added to his very interesting paper, to sustain his position

that our current American practice in regard to wind strains on bridges need not be essentially modified.

The following occur to me:

1. All calculations of wind pressures are assumed to be at right angles to the axis of the bridge. The resultant of this pressure is, however, I believe, in proportion to the sine of the angle, which the wind makes with the surface against which it is blowing, so that inasmuch as tornadoes (which alone, as Mr. Smith has pointed out, can exceed the pressures assumed) are not likely to strike the bridge very often at right angles, the probabilities of these extreme strains being exerted are still further reduced,

2. Not only is this pressure of 30 pounds per square foot, calculated, as stated by Mr. Smith, upon "twice the vertical surface of one truss," but the usual modes of estimating this truss surface, contain a still further element of safety.

Many engineers calculate this pressure upon the *developed* surface of the members of the truss, measuring around all the angles and projections; while Mr. Smith himself, as I understand from a private letter, estimates the exposed surface of *one truss*, by adding to the geometrical surface as shown on the drawings for upper chords and posts, one and a half times the surface of the ties, and twice the surface of the lower chord.

It is somewhat curious that nobody who has taken part in this discussion has yet called attention to the influence which the *form* of the bridge members has upon the resulting pressure. We all know that a convex surface presents *less* and a concave surface *more* resistance than a flat plane to the wind. I dare say that some of us have ascertained this fact experimentally with an umbrella, but I do not know that this knowledge has ever been applied to the calculation of the wind strains on bridges; or that any experiments have been made to determine the comparative resistance of various forms of bridge members.

I believe that Sir George Cayley found that a sphere offered a resistance of but 42 per cent. that of a flat plane taken through its mid section, and as the developed surface of the semi-sphere is equal to two great circles, the *average* of the pressure in that case per square foot is but 21 per cent. of what it would be upon a flat surface of equal area.

Again, an oblate spheroid of 3 diameters offers but 21 per cent. of the resistance of a plane through its mid section, so that the *average*

pressure per square foot, in that case, is but 6 or 7 per cent. of that of a plane of equal area.

The umbrella, which I mentioned a while ago, offers, I believe, a resistance of but 76 per cent. that of the plane drawn through its base, if turned with its convex side to the wind, while the concave side offers a resistance of 1.9 times that of the plane.

If we apply this knowledge to bridge members, we see at once that convex objects, like round ties and round closed columns, will offer less resistance, while trough-shaped posts and top chords will give more resistance than the plane surfaces shown upon the drawings. It is probably the general consideration of these facts which has led engineers to calculate the resistance upon a surface greater than that shown on the drawings, but it might be well to try a few experiments upon the actual wind resistance of various forms of bridge members, in order to know more accurately what is a safe allowance to make.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXXI.

(Vol. X.—May, 1881.)

AN EXAMINATION INTO THE METHOD OF DETERMINING WIND PRESSURES.

By F. COLLINGWOOD, Member A. S. C. E.

READ APRIL 6TH, 1881.

WITH DISCUSSION

By WILLIAM E. WORTHEN, Member A. S. C. E.

About two years ago, the writer prepared some notes on the subject of wind pressures, which, upon consideration, he decided not to present to the Society. Subsequent events have led to a modification of some of the views then held, and with these modifications they are now presented. On account of the inherent difficulties surrounding the subject, engineers have seemed to acquiesce in an empirical solution of the problem, and to decide that nothing better could be done. This is not in accordance with the spirit of investigation now extant; neither does it tend to economy or safety in construction; and it would seem that the time had come for a more thorough treatment of the matter.

In a paper by John Smeaton on the "Construction and Effect of Windmill Sails," read before the Royal Society May 31 and June 14, 1759, he gives a table of wind pressures, which have been quoted as authority in nearly all the hand and text books published since, and which is adopted by the United States Signal Service. He prefaces it thus :

"The following table, which was communicated to me by my friend Mr. Rouse, and which appears to have been constructed with great care, from a considerable number of facts and experiments, and which, having relation to the subject of this article, I here insert as he sent it to me; but at the same time must observe, that the evidence for those numbers where the velocity of the wind exceeds 50 miles in an hour, do not seem of equal authority with those of 50 miles and under. It is also to be observed that the numbers in column 3 (giving perpendicular force on one foot area in pounds avordupois) are calculated according to the square of the velocity of the wind, which, in moderate velocities, from what has been before observed will hold very nearly." (In a foot-note elsewhere he explains that certain experiments by Mr. Rouse were made with windmills by a special machine constructed so as to move the wheel (or sails), as a whole, through the air, and noting the weight lifted by the wheel with varying velocities of movement. The table is, therefore, apparently based on resistance by the fluid to motion through it, and *not* on impulse or presssure from the air. Whether these experiments are the ones on which the table is based is not stated, but may be inferred, although from what follows, it would seem that the table was computed largely).

Referring to Weisbach's Mechanics (Vol. I., § 390, Ed. 1848) the formula for the pressure tending to move a prismoidal body by the force of an unlimited stream of uniform velocity in which it is immersed is

$$P = (f_1 + f_2)\ \frac{v^2}{2g}\ d.$$

Where P = pressure in pounds per unit of cross-section.
v = velocity of stream in feet per second.
f_1 = co-efficient of pressure at up stream end.
f_2 = " " " down " "
d = weight of a unit of volume of the water.

He says that where the length parallel to the axis of the stream is zero (corresponding to a thin plate), Du Buat & Duchemin found that the sum of the co-efficients

$$(f_1 + f_2) \text{ will} = 1\tfrac{86}{100} \text{ or } P = 1.86 \frac{v^2}{64.4} d.$$

For a length of $\frac{l}{\sqrt{\text{section}}} = 1$, the co-efficient $= 1.47$.

" " " $= 2$, " $= 1.35$.

" " " $= 3$, " $= 1.33$, &c.

And as the ratio increases the coefficient continues to diminish.

Taking the case where it equals 1.86 as being nearest to the windmill sails, and substituting 0.07925 pounds as the weight of a cubic foot of air, we have where P = pressure in lbs. avordupois and V = velocity in miles per hour, $P = 0.00492\ V^2$. (1).

This equation gives results the same as those given by Rouse in the Smeaton tables.

Dubuat found that where the ratio $\frac{l}{\sqrt{\text{section}}} = o$ (or the case of a thin plate moved *against* water) the co-efficient became 1.25, or the pressure is 33 per cent. less than where the water moved against the plate. This is given in article "Resistance" in Brand & Coxe Cyclopedia as 1.43. In the same article a cylinder, with hemispherical end facing the stream is said to offer only half the resistance of the same with a plain end. Also that while the impulse of the stream against a plate 1ft. square gave the co-efficient as $1\frac{9}{10}$, a plate with one-tenth of a square foot of surface gave it as only $1\frac{4}{10}$, or nearly 20 per cent. less. Hutton's theoretical deductions, as stated by Weisbach, for a sphere moving against air give the co-efficient as increasing from 0.59 for a velocity of 1 metre to 1.10 for a velocity of 600 metres. In Hutton's mathematics the resistance to a spherical projectile at high velocities is given as 0.43 of that to a plain surface.

Of a hemisphere convex side forward 40 per cent.

" " plane " " 101 " &c.

In Appleton's "Cyclopedia of Applied Mechanics," 1880, is a table of pressures calculated by Mr. Alfred R. Wolff in which account is taken of the difference in density of the air at various temperatures. At a mean it differs but slightly from Smeaton's table, and would seem to be based on the same formula.

Prof. Cleveland Abbe in the article "Wind," in Appleton's American Cyclopedia, Vol. 16, writes as follows:

"Maxwell (see Proceedings of the Mathematical Society, 1870) has given theoretical formulas and curves showing the movements of par-

ticles of an incompressible fluid streaming past a moving obstacle; while Hagen (Berlin, 1872), has experimentally investigated these motions. Thiesen (Wild's Repertorium, 1875) has made a careful study of the experiments of Hagen and Dohrandt, and established the rule that the pressure of the wind against an inclined rectangular plate is really very nearly proportional to the square of the velocity, and the cosine of the angle of incidence of the wind, while the absolute value of the normal pressure is as given by Hagen's observations. The latter physicist (Berlin, 1874) has embodied the results of very careful observations at moderate velocities in a formula which converted into English measures is as follows :

$$P = (0.0028934 + 0.0001403\, p)\, SV^2 \qquad (2).$$

By introducing the term (p) Hagen has expressed the fact that the pressure depends to a considerable extent on the *shape* as well as the surface of the resisting body."

In this formula $P =$ the total pressure in pounds avordupois ; $p =$ the outline or perimeter of the exposed surface in feet ; $V =$ velocity in miles per hour ; $S =$ the area in square feet. The formula applies to plain surfaces (of no considerable depth) placed normal to the incident wind, and with the density of the air corresponding to a barometric height of 29.84 inches, and a temperature of 59° Fah.

The results from equations (1) and (2), together with Smeaton's and those of Hutton, are given in the table on the following page.

All are taken for one square foot of surface. It will be seen that Hagen's are about one-third less than Smeaton's, and Hutton's about midway between the two.

The diversity of views among practical men in determining the measure of surface acted upon, the probable wind to be resisted, and how the wind acts, are well shown by the evidence given at the inquest on the Tay Bridge disaster. These differences are greater even than those in the tables.

The journal *London Engineering*, January 2, 1880, in discussing the accident, takes the lee girder as exposing one-half as much surface to the wind as the windward girder, and the whole vertical surface of the train also as acted upon ; and deduces according to different supposed modes of failures pressures from $23\frac{1}{2}$ to $35\frac{6}{10}$ pounds per square foot, expressing the belief, however, that the maximum pressure did not exceed $25\frac{1}{2}$ pounds.

Velocity of Wind.		Pressure in Pounds per Sq Ft. Normal Plane Surface = P.						Names Given to Winds.		Classification by Smithsonian Institution.
Feet per Second.	Miles per Hour = V.	Rouse, Eq. (1).	Hutton.	Hagen, Eq. (2) Circular Surface.	Hagen, Eq. (2) Square Surface.	Hagen, Eq. (2) Triang'lar Surface.	Smithsonian Institution.	Smeaton—Rouse.	Smithsonian Institution.	
0.	0	0.	.....	.....	.....	.....	0.	.....	Calm	0
1.47	1	0.005	0.004	0.003	0.003	0.004	.....	Hardly perceptible.....	.....	.....
2.93	2	0.02	0.016	0.014	0.014	0.014	0.02	....	Very light breeze.....	1
4.4	3	0.044	0.036	0.03	0.031	0.032	.....	Just perceptible.		
5.87	4	0.079	0.065	0.054	0.055	0.057	0.08	.....	Gentle breeze.....	2
7.33	5	0.123	0.101	0.085	0.086	0.088	.....	Gentle, pleasant, wind.		
14.67	10	0 492	0.405	0.339	0.345	0.353	.....			
17.6	12	0.711	0.583	.....	.....	.....	0.75	Pleasant, brisk, gale.....	Fresh wind.....	3
22.	15	1.107	0.911	0.763	0.777	0.795	.....			
29.34	20	1.968	1.62	1.356	1.382	1.413	.....	Very brisk.		
36.67	25	3.075	2.531	2.119	2.159	2.208	3.	.....	Strong wind.....	4
44.01	30	4.429	3.645	3.052	3.109	3.18	.....	High winds.		
51.34	35	6.027	4.961	4.154	4.232	4.328	6.	.....	High wind.....	5
58.68	40	7.873	6.48	5.425	5.527	5.653	.....	Very high.		
66.01	45	9.963	8.201	6.866	6.996	7.155	10.	.....	Gale.....	6
73.35	50	12.3	10.125	8.476	8.637	8.833	.....	A storm or tempest.....	.....	.....
88.02	60	17.715	14.58	12.208	12.437	12.719	18.	A great storm.....	Strong gale.....	7
110.	75	27.65	22.781	.....	.....	.....	.....	.....	Violent gale.....	8
117.36	80	31.49	25.92	21.701	22.11	22.613	.....	A hurricane.....	.....	.....
132.03	90	39.852	32.805	.....	.....	.....	.....	.....	Hurricane.....	9
146.70	100	49.2	40.5	33.908	34.546	35.332	.....	A hurricane that tears up trees and carries buildings before it.....	Most violent hurricane..	10

In subsequent numbers of *Engineering*, evidence is given as follows:

Mr. Allan Stewart placed the pressure at 75 pounds. Mr. B. Baker placed it at 15 pounds; he had experimented on glass in frames, and anything like 40 pounds per square foot would have destroyed the signal boxes. He had never seen a structure blown down which was capable of withstanding 20 pounds, and he looked upon that as the maximum pressure to be taken for structures of any kind. Fences capable of withstanding only 13 pounds had withstood storms in all situations.

He states that the French engineers assume $34\frac{6}{10}$ pounds as the greatest pressure a train can bear without overturning. One of their engineers had gone into an examination of chimneys, and had assumed an arbitrary figure of 55 pounds as the force they had to withstand, and this figure was now taken as the pressure against bridges, &c. The same has been taken by Rankine.

Mr. Baker said that in his own work he assumes 28 pounds, and varies the *factor* of *safety* with circumstances.

Dr. Pole and Mr. Stewart estimate the pressure required to overturn the bridge with no train upon it at $37\frac{4}{10}$ pounds, and with the train, at $34\frac{1}{3}$ pounds (also, $28\frac{1}{2}$ pounds as needed to overturn the lightest carriage in the open, and 33 pounds when containing 8 passengers and shielded by the bridge members).

Mr. Law places the same at $36\frac{2}{3}$ and $32\frac{2}{3}$, respectively, and that 40 pounds were needed to overturn the lightest carriage in the train.

Prof. Airy states that during the gale of December 8, 1872, the greatest velocity recorded was 57 miles per hour, and he thought the pressure had reached 50 pounds per foot. The maximum pressure recorded at Greenwich was 40 pounds and then the instrument gave way.

He had estimated the pressure in the valley of the Tay at 50 to 100 pounds. "The valley runs deep, and would make a channel for the wind." He thought 120 pounds ought to be provided for, but this would allow a large margin for safety.

He did not know whether such pressures ever obtained simultaneously over so large an area as the Tay Bridge. In a letter respecting the Forth Bridge, he had stated "that over very limited surfaces and for very limited times the wind pressure was sometimes known to reach 40 pounds in England, and in Scotland would probably amount to

more." The greatest that might be exerted over the whole extent of such a surface as the Tay Bridge was 10 pounds.

Mr. Gilke, previous to the accident, read a paper in which he took the total surface exposed at about two-thirds of the amount assumed by *London Engineering*, and the pressure needed to overtun a carriage at $39\frac{2}{10}$ pounds.

Prof. Stokes, of Cambridge University, at the inquest, said he thought 10 pounds per square foot, on a plain surface, as too low. The more rapid the *fluctuations* in the wind, the less their extent laterally. As far as experiment went the pressure was found to be nearly in proportion to the area of surface. He should like to see an exhaustive series of experiments made on large surfaces. There were difficulties in recording velocities of the wind for short spaces of time. There is a difficulty in connecting the velocities with the pressures. Hydrostatically measured, a pressure of one pound on the square foot gave a velocity of 20 miles per hour. Experiment had shown that about 20 per cent. must be added to what was called the standard pressure (that on the surface of water in a tube), in order to get the algebraic sum of pressures per foot on both sides of a plate.

Mr. Scott, Secretary of the Scottish Meteorological office, said: "The greatest velocity registered at Glasgow (during the storm which destroyed the bridge), for any continuous 60 minutes, was 71 miles; but for one five minutes interval, it was 96 miles, for one 3 minutes interval, 120 miles, and for three others, 110 miles per hour." The storm-gust at the Tay Bridge was probably 300 feet wide, and some gusts may be restricted to 30 or 40 feet width.

Passing to other known disasters from wind pressure, the destruction of the Arrah road bridge across the Sone canal in India, is worthy of mention, since the weights, friction, &c., have been accurately calculated (see *London Engineering*, June 25, 1880).

This was 99 feet long, 15 feet wide, and continuous over two spans of 45 feet each. It was destroyed by a very narrow belt of wind. There were no holding down bolts, and the structure was lifted and pushed bodily off the supports, with almost no injury to the masonry.

Taking the whole vertical surface of both trusses, and the wind horizontal, and assuming the friction at 50 per cent. of weight, the pressure on the supposition of the wind striking the uncompleted span first, would be $20\frac{8}{10}$ pounds. If moved bodily, it must have been $29\frac{6}{10}$

pounds. Calcutta was the nearest point where records were kept, and during the cyclone 50 pounds were registered.

Coming nearer home, Mr. Francis in his report on the chimneys of the Lawrence Manufacturing Company (published in *Engineering News*, Aug. 28, 1880), states the highest recorded pressure for 50 years past on the New England coast to be 50 pounds.

Mr. C. Shaler Smith, in his paper before this Society of December 15, 1880, states pressures in the Western States at from 18 to 93 pounds, but does not state how the results were arrived at.

Mr. W. Hartnell, in a discussion in *London Engineering* of January 2, 1880, states, respecting the gale in 1868, during which a momentary pressure of 80 pounds was recorded at the Bidston Observatory in Liverpool, that on the side of the observatory farthest from the sea, the pressure was only 38 pounds. He says further, that behind a flat plate a *partial vacuum* is formed by wind rushing past the edges. One per cent. of vacuum would give an increase of pressure per foot of 21 pounds. He says that narrow, flat bars, and open structures generally, offer a *maximum* resistance per foot of area. So that a statement of so much pressure means nothing, unless we know just how it is taken. He also says that a squall in still air will travel, say 20 miles per hour, and will blow at 30 miles for a short time, thus "exerting twice the pressure that might have been expected." In other words, that the maximum pressure is twice that due to the average velocity of the wind.

It is not necessary to go farther to illustrate the conflict of opinion which surrounds every branch of this subject.

There can be no doubt that much of the uncertainty arises from the use of imperfect apparatus, the *inertia* of the parts being entirely overlooked. On this point the article "Anemometer," in the *Cyclopedia Brittannica*, although written some years ago, is in a measure true now. It says: "If the currents of air were anything like uniform, it would be a comparatively simple matter to deduce the velocity from the pressure; but their variability is so great, that the relations between them become unworkably complex. We know from the elementary principles of dynamics that the pressure at any instant will vary as the square of the velocity. Obviously, therefore, the relative variations of the pressure will be *twice* as great as those of the velocity; and the *latter* are too great, as we find them to encourage us to double them artificially. It must be remembered also, that from the *inertia* of the indicating ap-

paratus, errors will in every case arise, and *these* also will be doubled if we take the pressure instead of the velocity indications. From all this it will appear that comparatively little importance is to be attached to the earlier, and to *all* statistical anemometry."

As an example of the apparatus used for recording pressures, may be instanced that at the Central Park, in New York, as described in the report for the year ending December 31, 1869. A storm occurred December 18, 1869, which is fully recorded in the same report. The apparatus consists of a hollow metal cylinder 2 feet high and 1 foot diameter, suspended with its axis vertical by a chain, and having a chain extending from its lower end, and connecting with a spring balance. As the wind blows the cylinder to one side, the spring is extended, and a pencil attached to the spring is moved up, and records its excursion on a sheet of paper traveled slowly past it by clock work. By testing the power required to extend the spring to various points, it would seem that a fair measure of the pressure might be obtained.

On examining the record of the storm mentioned, however, it is seen to be a series of quick strokes outward, and back again nearly to the zero line. So much is this the case, that the paper is shaded almost black near the zero line, becoming lighter as we pass from it, and with a few detached strokes of no appreciable duration at the extreme pressures. The *greatest* pressure recorded is 22 pounds, and that only twice, and at long intervals. Of 18 pounds pressure or over, there were four at intervals of 12½, 30 and 35 minutes respectively. At 15 pounds and over, about 10, with intervals of 2½ to 30 minutes. These are approximations, as it is difficult to measure from the lithograph.

It is evident that these records are vitiated by the *inertia* of the cylinder, just as when a pound weight is suddenly placed upon a spring balance, about 2 pounds will be momentarily indicated.

The instrument can in no case, however, be considered a scientific one, and there seems to be a similar difficulty with most of those employed.

Another source of error is well pointed out by Mr. Ashbel Welch, in his paper before the Society, of May 25, 1880.

If we take the fundamental formula $h = \frac{v^2}{2g}$ and calculate the pressures corresponding to air at the standard temperature and density, the results given will be very closely one-half only of those given by Rouse

and Smeaton. We know, however, that the actual pressures from the wind are greater. Could each particle of air give up all its motion, and get out of the way of those to follow without affecting the latter, the result would be rigorously true. There is, however, a piling up or condensation at the front or incident surface and a lateral flow—such, that the stream to be considered has virtually a larger section or base than the surface acted upon. In addition, there is the partial vacuum in the rear, noted by Mr. Hartnell, but first pointed out by some of the earlier experimenters on the subject.

These results, as we have seen, are modified not only by the shape of the incident surface, but also very largely by the length of the body acted upon in the direction of the wind current.

To sum up from the data given, we find the following sources of error, if we consider the maximum pressure of the wind, upon the exposed surface of a structure, as required by the engineer in proportioning its parts :

1st. Imperfect anemometers, vitiating results by the inertia of the moving parts, thus tending to make results too large.

2d. The difficulty of translating velocities into pressures, tending to make results too *small*, since the velocity recorded is an average over a period of time, and not that at the instant of greatest pressure.

3d. The data on record are not exact. To serve the purposes of science every circumstance as to size of parts, character and shape of surface, size of openings, height above ground, and location, must be noted.

4th. Almost all the records are based upon the assumption of a horizontal wind, whereas all experience shows that this is incorrect, and that the largest possible projection is liable to be the one acted upon.

In reference to height above ground, and direction of wind, the following memoranda are to the point.

In *Engineering News* of September 11, 1880, is an article referring to experiments with a specially devised anemometer, by Mr. S. Fraser, of the Scottish Meteorological Society. He says that wind currents are much modified by the ground over which they pass. For example, in front of the Royal Observatory in Edinburgh, their deflection from the horizontal was about 45°. On the level ground it was not over 15°, except in one case near Edinburgh, when it suddenly assumed nearly a *vertical* position. In the case already mentioned of the Arrah road

bridge, it would seem that there was a strong lifting, as well as a horizontal force, to have removed the bridge with so little damage to the masonry.

As to the effect of height there is in the monthly weather report of the U. S. Signal Service for September, 1880, the following quotation from a "Report on Results of Wind Observations, made with small cup and dial anemometers at different heights, by Thomas Stevenson, M. I., C. E., published in the Journal of the Scottish Meteorological Society.

"Although additional observations are much wanted at high levels, the results, so far as appears from the observations on winds varying from 2 miles an hour to 44 miles an hour, show:

1st. That spaces passed over in the same period of time by the wind increase with the height above the sea level, or above the surface of the ground.

2d. The curves traced out by those variations of velocity (from 15 feet to 50 feet above the surface of the ground, and possibly higher) coincide most nearly with parabolas having their vertices in a horizontal line 72 feet below the surface.

3d. Between 15 feet and the ground surface there is great disturbance of the currents, so that the symmetry of the curves is destroyed.

4th. The parameters of these parabolas increase directly in the ratio of the squares of the velocities of the different gales :—If x be taken as the velocity of the wind at H feet above the ground the parameter of the corresponding parabola is $\left(\frac{x^2}{H+72}\right)$ and as x varies, the parameter will vary as x^2, or as the square of the velocity of the gale.

5th. In order to render wind observations comparable, all anemometers should if possible be placed at an uniform height above the ground, and that standard height should not be lower than 20 feet above its surface but, were it generally, practicable, 50 feet, or a still greater height would be better.

6th. When it is desired to find for *small heights* the velocity V at any point H feet above the ground, from the known velocity v at a height h feet above the ground (h being *above* 15 feet), the formula is $V=v\sqrt{\frac{H+72}{h+72}}$; when H is above 50 feet above ground, the V got from the formula is slightly in excess of the actual velocity. When it is

wanted to ascertain the velocity for *great heights* above the sea level, the approximately correct formula, which is believed to be sufficiently correct for practical purposes, is $V = v\frac{H}{h}$.

7th. It would be well for meterologists to adopt this reduction formula and to express all wind velocities as referred to the height of 50 feet above the ground. This formula in this case becomes $V = v\sqrt{\frac{122}{h+72}}$."

It is no wonder after what has been given, that engineers disagree as to the pressure of wind even in a given case. We find one man taking the vertical projection of one truss, another of one and a half, another of two, and so on, and almost no reference made to any other portion of the structure or to any different projection.

Again the same pressure is taken for a bridge in a clear, open space, or for a gorge where, as Mr. Cooper (Vol. IX—394 of Transactions) has pointed out—there may be developed "local currents of much greater velocity," than the average of the storm.

Again, the same pressure is ordinarily taken for a short bridge, as for a long one, and we have a common agreement, among observers that the violence of storms is exerted over only limited areas, and is progressive in its character. There is also the other fact, that for structures of great span, the danger from repeated or "rhythmic" gusts (spoken of by Mr. Cooper) is exceedingly small. An examination of the storm record, given in the Central Park report, will show that the gusts are hardly such as to cause this danger to structures whose period of vibration is very slow.

The experiments and observations needed to secure a scientific treatment of the whole subject, and uniformity of practice among engineers, must be more exhaustive than any heretofore made; but we shall never reach the desired end by assuming that it is unreachable. In the hope that this review may assist in promoting a movement in the right direction, this paper is respectfully submitted.

P. S.—The writer would submit the following copy of a letter just received from Prof. Cleveland Abbe, of Washington, hoping that its suggestions may be favorably received by the Society.

ARMY SIGNAL OFFICE,
WASHINGTON, D. C., February 8, 1881.

Mr. COLLINGWOOD,

Assistant Engineer, &c. :

SIR,—In reply to yours of the 5th inst., I will say that the relation between wind pressure and velocity has not as yet formed the subject of any special investigation by the officers of this office, as it is of minor importance in the study of weather and climate. But the practical importance of this subject, to engineers and others, is such, that this office has, on several occasions, considered the propriety of establishing at favorable stations, such as Cape Hatteras and Mount Washington, apparatus for observing simultaneously both force and velocity during gales and hurricanes.

There has always existed, however, considerable diversity of opinion as to the apparatus most appropriate to this investigation, and I should be glad to receive from the Society of Engineers, or other experts, any suggestions upon this subject.

Not having access to the bulletins of your Society, I can scarcely judge how far you have gone in the consideration of this very difficult subject, but I will append a list of titles of memoirs that you may find convenient to refer to.

I should be glad to obtain copies or titles of any memoirs relating to this subject which have been published in America.

Very respectfully yours,

CLEVELAND ABBE.

T. R. ROBINSON.—Description of an improved Anemometer, &c. Trans. Royal Irish Academy. Vol. XXII. Dublin, 1850.

G. H. L. HAGEN.—Ueber den Widerstand der Luft gegen Planscheiben, &c. Abhandlungen d. Akad. d. Winnenschaften. Berlin, 1874. An abstract also to be found in Pogg. Annalen, Vol. 152, p. 95.

S. CAVALLERA.—Di un apparecchio per la determinazione, Sperimentale delle costanti, degli anemometri. Torino, Atti Accad. Sci., VIII. 1872–3, pp. 663–683.

F. STOW.—On large and small anemometers. Read January 17, 1872. Quarterly Journal of the Meteorological Society. April, 1872. Vol. I, pp. 41–49.

F. Dohrandt.—Bestimmung der Anemometer Constanten. St. Petersburg, 1874, p. 60.
Art. 5, Vol. IV., Wild's Repertorium.

H. Thiesen.—Zur Theorie der Wind Stärke-Tafel. St. Petersburg, 1875.
Art. 9, Vol. IV. of Wild's Repertorium für Meteorologie.

" same. " 11, Vol. V., " "

T. R. Robinson.—Proceedings Royal Irish Acad. 2d Ser., Vol. II, January, 1876, and abstract in Zeitschrift Oesterreichischen Gesellschaft fur Meteorologie.

H. Wild.—Ueber den gegenwartigen Zustand der Anemometer verification. Bulletin de l'Acad. de St. Petersburg. Vol. XXIII., p. 176, December, 1876.

F. Dohrandt.—Bestimmung der Anemometer Constanten (Fort Setzung), p. 28. St. Petersburg, 1878.
Art. VI., Wild's Repertorium für Meteorologie.

William E. Worthen.—I would ask Mr. Collingwood if he knows of any instrument by which to determine wind pressure. Some years since I had occasion for such a one, and went to Mr. James Green, the mathematical instrument maker. He showed me some, but said that they were not reliable, and that there were none manufactured that he would indorse, nor do I find since then any new form. Wind pressure is, I believe, generally estimated from velocity measures, but in pursuing my inquiry on these I consulted Charles B. Richards, one of our members, who had made experiments with two of Casella's anemometers, in his arrangements for the ventilation of the Connecticut State House; the results are published in the Journal of the Franklin Institute, May, 1875. Each instrument was tested by the maker, and a table of corrections furnished with each, and yet Mr. Richards reports, that the indications of the two meters differed so widely that little confidence could be put in them. I have never been able to arrive satisfactorily at either the plus or windward pressure on a structure, or the minus or leeward. In the matter of ventilation of houses—I take it into consideration for the furnace air-ducts in the construction of chimneys—I follow examples that have stood. There is one at Hastings-on-the-Hudson, a part of the wreck

of a sugar house, that ought, I think, to have blown down long ago. In "Silliman's Journal," some forty odd years since, I read of fowls being taken up in a whirlwind, and their feathers being blown out by the explosion of the air in their quills, showing that there was a considerable vacuum in the storm centre. Mr. Chesbrough suggests, whether there might not be a wind pressure instrument made on the principle of a pendulum, in which the the force might be estimated by the amount that the pendulum is swung out of plumb by it. It would seem that the list of a ship under canvass by the wind might offer some data of calculation, but they are unsatisfactory. M. Perrodil, in the "Annales dés Ponts et Chaussées of 1877," gives a description of a stream gauge in which the velocity of the current is determined by the torsion of a wire. I have full drawings from him, and price.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXXII.

(Vol X.—June, 1881.)

ADDRESS

OF

JAMES BICHENO FRANCIS, President, A. S. C. E.,

At the Thirteenth Annual Convention of the Society, at Moutreal, June 15, 1881.

You have assembled in Convention for the first time outside the limits of the United States, and I congratulate you on the selection of this beautiful city, in which, and its immediate neighborhood, there are so many interesting engineering works, constructed with the skill and solidity characteristic of the British school of Engineering. Nine of our members are Canadian Engineers, which must be the excuse of the other members for invading foreign territory.

The Society was organized November 3, 1852, and actively maintained up to March 2, 1855. Eleven only of the present members date from this period. October 2, 1867, the Society was reorganized on a wider basis, and from that time to the present it has been constantly increasing in interest and usefulness.

The membership of the Society is now as follows :

Honorary members	11
Corresponding members	3
Members	491
Associates	21
Juniors	57
Fellows (not including those who are members)	53
Total	636
Subscribers to the Building Fund	99

During the last year we have lost six members by death, and five by resignation, and fifty-six new members have been elected and qualified.

The most interesting event to the society since the last Convention, has been the purchase of a house, in the City of New York, as a permanent home, at a cost of $30 000. This has been accomplished, so far, without taxing the resources of the Society, the required payments having been met by subscription. The sum of $11 900 had been subscribed to the building fund, up to the 25th ultimo, by seventy members and twenty-nine friends of the Society who are not members. The subscription is still open, and it is expected that large additions will be made to it by members and their friends to enable the Society to make the remaining payments without embarrassment.

Meetings of the Society are held twice in each month, during ten months in the year, for the reading and discussion of papers and other purposes ; the new house affords much better accommodations for these purposes than we have ever had before, and also for the library, which now contains 8 850 books and pamphlets, and is constantly increasing. A catalogue of the library is being prepared. Part I., embracing Railroads and the Transactions of Scientific Societies, has been printed and furnished to members.

Water-Power.

Water-power in many of the States is abundant and contributes largely to their prosperity. Its proper development calls for the services of the Civil Engineer, and as it is the branch of the profession with which I am most familiar, I propose to offer a few remarks on the subject.

The earliest applications were to grist and saw mills ; carding and fulling mills soon followed ; these were essential to the comfort of the

early settlers who relied on home industries for shelter, food and clothing, but with the progress of the country came other requirements.

The earliest application of water-power to general manufacturing purposes, appears to have been at Paterson, New Jersey, where "The Society for Establishing Useful Manufactures" was formed in the year 1791. The Passaic River at this point furnishes, when at a minimum, about eleven hundred horse-power, continuously night and day.

The water-power at Lowell, Massachusetts, was begun to be improved for general manufacturing purposes in 1822. The Merrimack River at this point has a fall of thirty-five feet, and furnishes, at a minimum, about ten thousand horse-power during the usual working hours.

At Cohoes, in the State of New York, the Mohawk River has a fall of about one hundred and five feet, which was brought into use, systematically, very soon after that at Lowell, and could furnish about fourteen thousand horse-power during the usual working hours, but the works are so arranged that part of the power is not available at present.

At Manchester, New Hampshire, the present works were commenced in 1835. The Merrimack River at this point has a fall of about fifty-two feet, and furnishes, at a minimum, about ten thousand horse-power, during the usual working hours.

At Lawrence, Massachusetts, the Essex Company built a dam across the Merrimack River, commencing in 1845, and making a fall of about twenty-eight feet, and a minimum power, during the usual working hours, of about ten thousand horse-power.

At Holyoke, Massachusetts, The Hadley Falls Company commenced their works about 1845, for developing the power of the Connecticut River at that point, where there is a fall of about fifty feet, and at a minimum, about seventeen thousand horse-power during the usual working hours.

At Lewiston, Maine, the fall in the Androscoggin River is about fifty feet; its systematic development was commenced about 1845, and with the improvement of the large natural reservoirs at the head waters of the river, now in progress, it is expected that a minimum power, during the usual working hours, of about eleven thousand horse-power will be obtained.

At Birmingham, Connecticut, the Ousatonic Water Company, have developed the water-power of the Housatonic River by a dam giving twenty-two feet fall, furnishing, at a minimum, about two thousand horse-power, during the usual working hours.

The Dundee Water and Land Company, about 1858, developed the power of the Passaic River, at Passaic, New Jersey, where there is a fall of about twenty-two feet, giving a minimum power, during the usual working hours, of about nine hundred horse-power.

The Turner's Falls Company, in 1866, commenced the development of the power of the Connecticut River at Turner's Falls, Massachusetts, by building a dam on the Middle Fall, which is about thirty-five feet, and furnishes a minimum power, during the usual working hours, of about ten thousand horse-power.

I have named the above water-powers as being developed in a systematic manner from their inception, and of which I have been able to obtain some data. In the usual process of developing a large water-power, a company is formed who acquire the title to the property, embracing the land necessary for the site of the town, to accommodate the population which is sure to gather around an improved water-power. The dam and canals or races are constructed, and mill sites with accompanying rights to the use of the water are granted, usually by perpetual leases, subject to annual rents. This method of developing water-power is distinctly an American idea, and the only instance where it has been attempted abroad, that I know of, is at Bellegarde, in France, where there is a fall in the Rhone of about thirty-three feet. Within the last few years works have been constructed for its development, furnishing a large amount of power, but from the great outlay incurred in acquiring the titles to the property, and other difficulties, it has not been a financial success.

The water-powers I have named are but a small fraction of the whole amount existing in the United States and the adjoining Dominion of Canada. There is Niagara, with its two or three millions of horse-power; the St. Lawrence, with its succession of falls from Lake Ontario to Montreal; the Falls of St. Anthony, at Minneapolis, and many other falls, with large volumes of water, on the upper Mississippi and its branches. It would be a long story to name even the large water-powers, and the smaller ones are almost innumerable. In the State of Maine a survey of the water-power has recently been made, the result, as stated in the official report, being "between one and two millions of horse-powers," part of which will probably not be available. There is an elevated region in the northern part of the South Atlantic States, exceeding in area one hundred thousand square miles, in which there is a vast amount

of water-power, and being near the cotton fields, with a fine climate, free from malaria, its only needs are railways, capital and population to become a great manufacturing section.

The design and construction of the works for developing a large water-power, together with the necessary arrangements for utilizing it, and providing for its subdivision among the parties entitled to it, according to their respective rights, affords an extensive field for civil engineers, and, in view of the vast amount of it, yet undeveloped, but which with the increase of population and the constantly increasing demand for mechanical power, as a substitute for hand labor, must come into use, the field must continue to enlarge for a long time to come.

There are many cases in which the power of a water-fall can be made available by means of compressed air, more conveniently than by the ordinary motors. The fall may be too small to be utilized by the ordinary motors; the site where the power is wanted may be too distant from the water-fall, or it may be desired to distribute the power in small amounts at distant points. A method of compressing air by means of a fall of water has been devised by Mr. Joseph P. Frizell, C. E. of St. Paul, Minnesota, which, from the extreme simplicity of the apparatus, promises to find useful applications.* The principle on which it operates is, by carrying the air in small bubbles in a current of water down a vertical shaft to the depth giving the desired compression, then through a horizontal passage, in which the bubbles rise into a reservoir near the top of this passage, the water passing on and rising in another vertical or inclined passage, at the top of which it is discharged, of course, at a lower level than it entered the first shaft. The formation at water-falls is usually rock, which would enable the passages and the reservoir for collecting the compressed air to be formed by simple excavations with no other apparatus than that required to charge the descending column of water with the bubbles of air, which can be done by throwing the water into violent commotion at its entrance, and a pipe and a valve for the delivery of the air from the reservoir.

The transfer of power by electricity is one of the problems now engaging the attention of electricians, and it is now done in Europe in a small way. Sir William Thompson stated, in evidence before an English Parliamentary committee, two years ago, that he looked "forward to the

* Journal of the Franklin Institute for September, 1877.

"Falls of Niagara being extensively used for the production of light and "mechanical power over a large area of North America," and that a copper wire half an inch in diameter would transmit twenty-one thousand horse-power from Niagara to Montreal, Boston, New York or Philadelphia. His statements appear to have been based on theoretical considerations, but there is no longer any doubt as to the possibility of transferring power in this manner; its practicability for industrial purposes must be determined by trial. Dr. Paget Higgs, a distinguished English electrician, is now experimenting on it in the City of New York.

Great improvements in reaction water-wheels have been made in the United States within the last forty years. In the year 1844 the late Uriah Atherton Boyden, a civil engineer of Massachusetts, commenced the design and construction of Fourneyron turbines, in which he introduced various improvements and a general perfection of form and workmanship, which enabled a larger percentage of the theoretical power of the water to be utilized than had been previously attained. The great results obtained by Boyden with water-wheels, made in his perfect manner, and, in some instances, almost regardless of cost, undoubtedly stimulated others to attempt to approximate to these results at less cost, and there are now many forms of wheel of low cost, giving fully double the power, with the same consumption of water, that was obtained from most of the older forms of wheels of the same class.

Anchor Ice.

A frequent inconvenience in the use of water-power in cold climates is that peculiar form of ice called anchor or ground ice. It adheres to stones, gravel, wood and other substances forming the beds of streams, the channels of conduits and orifices through which water is drawn; sometimes raising the level of water courses many feet by its accumulation on the bed, and entirely closing small orifices through which water is drawn for industrial purposes. I have been for many years in a position to observe its effects, and the conditions under which it is formed.

The essential conditions are, that the temperature of the water be at its freezing point, and that of the air below that point; the surface of the water must be exposed to the air and there must be a current in the water.

The ice is formed in small needles on the surface, which would remain there and form a sheet if the surface was not too much agitated,

except for a current or movement in the body of water sufficient to maintain it in a constant state of intermixture. Even when flowing in a regular channel, there is a continual interchange of position of the different parts of a stream; the retardation of the bed causes variations in the velocity which produce whirls and eddies, and a general instability in the movement of the water in different parts of the section. The result being that the water at the bottom soon finds its way to the surface, and the reverse. I found by experiments on straight canals, in earth and masonry, that colored water discharged at the bottom reached the surface at distances varying from ten to thirty times the depth.* In natural water courses, in which the beds are always more or less irregular, the disturbance would be much greater. The result is, that the water at the surface of a running stream does not remain there, and when it leaves the surface it carries with it the needles of ice, the specific gravity of which differs but little from that of the water, which, combined with their small size, allows them to be carried by the currents of water in any direction. The converse effect takes place in muddy streams. The mud is apparently held in suspension, but is only prevented from subsiding by the constant intermixture of the different parts of the stream; when the current ceases, the mud sinks to the bottom, the earthy particles composing it being heavier than water, would sink in still water in times inversely proportional to their size and specific gravity. This, I think, is a satisfactory explanation of the manner in which the ice formed at the surface finds its way to the bottom; its adherence to the bottom, I think, is explained by the phenomenon of *regelation*, first observed by Faraday; he found that when the wetted surfaces of two pieces of ice were pressed together they froze together, and that this took place under water, even when above the freezing point. Professor James D. Forbes found that the same thing occurred by mere contact, without pressure, and that ice would become attached to other substances in a similar manner. Regelation was observed by these philosophers in carefully arranged experiments with prepared surfaces, fitting together accurately, and kept in contact sufficiently long to allow the freezing together to take place. In nature these favorable conditions would seldom occur in the masses of ice commonly observed, but we must admit, on the evidence of the recorded experiments, that, under

* Paper CLX. in the Transactions of the Society, 1878, vol. VII., pages 109, 168.

particular circumstances, pieces of ice will freeze together or adhere to other substances in situations where there can be no abstraction of heat.

When a piece of ice of considerable size comes in contact under water, with ice or other substance, it would usually touch in an area very small in proportion to its mass, and other forces acting upon it, and tending to move it, would usually exceed the freezing force, and regelation would not take place. In the minute needles formed at the surface of the water, the tendency to adhere would be much the same as in larger masses touching at points only, while the external forces acting upon them would be extremely small in proportion, and regelation would often occur, and of the immense number of the needles of ice formed at the surface, enough would adhere to produce the effect which we observe and call anchor ice. The adherence of the ice to the bed of the stream or other objects, is always down stream from the place where they are formed; in large streams it is frequently many miles below; a large part of them do not become fixed, but, as they come in contact with each other, regelate and form spongy masses, often of considerable size, which drift along with the current, and are often troublesome impediments to the use of water-power.

Water-powers supplied directly from ponds or rivers, or canals frozen over for a long distance immediately above the places from which the water is drawn, are not usually troubled with anchor ice, which, as I have stated, requires open water, up stream, for its formation.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CCXXIII.

(Vol. X.—July, 1881.)

THE RE-ENFORCEMENT OF THE ANCHORAGE AND RENEWAL OF THE SUSPENDED SUPERSTRUCTURE OF THE NIAGARA RAILROAD SUSPENSION BRIDGE.

BY L. L. BUCK, MEMBER A. S. C. E.

PRESENTED AT THE 13TH ANNUAL CONVENTION, JUNE 15TH 1881.

Mr. President, and Gentlemen of the American Society of Civil Engineers : Having completed the work in question, I have, at the request of several of the members of the Society, prepared the following paper, believing that it will possess some points of interest to such members as are engaged in bridge building.

When the project of spanning the Niagara river with a suspension bridge for railroad purposes began to be discussed, grave doubts as to its practicability were expressed. This feeling was shared by some quite prominent engineers, till the work was very nearly ready for the passage of trains.

The bridge has now been in constant use for nearly twenty-six years. Yet to the traveling public it has always been an object of solicitude. The location of the bridge would naturally excite the fears of timid people who can only form an opinion based upon their faith in the man who undertakes to build a bridge in such a place, while even the more courageous and intelligent have felt that causes might be at work which would some time effect its destruction.

These fears finally led to a thorough inspection of the cables and of such portions of the anchorage as were accessible or would be liable to injury, and also to the subsequent re-enforcement and renewal which are the subjects of this paper.

Before entering upon an account of those operations it is necessary to give, for the benefit of those members who never visited the bridge in question, a general description of the structure as it was.

Description of Old Work.

I. *Locality.*—The bridge is about two miles below the Falls. The formation over which the Niagara river flows, and through which it is supposed to have cut its way, from a short distance above Lewiston to where the Falls now are, consists of nearly level strata of rock. These strata, from the surface to a depth of about one hundred and eighty feet, are principally composed of limestone. Underlying this portion is a bed of red sandstone about forty feet thick, or extending about to the surface of the water of the river.

The surface stratum is solid, especially on the New York side of the river, and has a thickness of about 15 feet in the vicinity of the anchorage. This is followed by a stratum of limestone shale, interspersed with flint. Following this is a solid stratum of rock about 20 feet to 30 feet thick.

The gorge at the level of the surface of the rock is about 730 feet wide measured on centre line of the bridge.

The surface of the rock on the Canada side is about 10 feet higher than that on the New York side.

II. *The Bridge.*—The general description of the bridge is as follows :

1st. Four cables, resting on the tops of two masonry towers at each end of the span, have their ends anchored to the rock.

The length of span between centres of towers is 821 feet.

Two of the cables at mean temperature have a versed sine of 54 feet, and are denominated upper cables.

The other two cables have a versed sine of 64 feet, and are called lower cables.

The planes of the curves of the cables on each side are inclined so as to bring their lowest points nearer together than they are at the tops of the towers. From the tops of the towers to the anchorage the cables diverge from the centre line sufficiently to make their pressure upon the towers vertical.

The portions of the cable on each side of the tower and adjacent to it form the same angle with the vertical. Hence the anchorage of the upper cable is about 37 feet further from the tower than that of the lower cable.

2d. Suspended superstructure. This consists of two floors, one above the other, connected together at each side by posts and truss rods, the latter inclining each way, in such a manner as to form a trussed tube The object of the trusses is not to aid in supporting the load, but to prevent excessive undulation.

The upper floor is secured to the upper cables by means of wire rope suspenders, and it carries the railroad track.

The lower floor is in the same manner secured to the lower cable, and forms the foot and carriage way.

The structure is secured against lateral vibrations by means of wire rope guys from each side of the lower floor to rocks on each bank of the river.

Construction of Parts.

I. *Cables.*—Each cable is composed of 3 640 iron wires, scant No. 9 (Birmingham gauge), first laid in seven separate strands or bundles of straight wire made continuous by splicing. They formed a loop at each end which rested in a groove around the outside of a cast iron U-shaped shoe. Each strand was built with a much less deflection than what the cables now have in order to facilitate their adjustment, and when each was completed it was lowered into place, and fastened to the anchor-bars, as will be described under head of anchorage. After the seven strands were completed and adjusted, they were served closely with wire throughout their length, with the exceptions of those portions on the top of the towers, and about 13 feet of their length at each end, thus forming one cylindrical bundle 10¼ inches in diameter.

II. *Anchorage.*—The dotted curved lines in Figure 1, Plate XXIV, show the profiles of the chains from the ends of the cable to where they enter the rock. The stone supports under each joint of the chain are shown in their respective positions in the wall enclosing the chains.

The plan and elevation, Figure 2, Plate XXIV, show the method of securing the ends of the cables to the ends of the chains. The three shoes (*a*) alternate with four bars, and the four shoes (*b*) alternate with five bars, and are secured by pins passing through heads of bars and openings of shoes. The other ends of all the nine links are secured to the next length of chain by one pin passing through all the heads.

Pits were sunken into the rock to a depth of 25 feet, their dimensions in plan being 3 feet x 7 feet. At the bottom they were enlarged to 7 feet square for the reception of heavy cast-iron anchor plates. The chains entered the rock vertically, and passed downward to the plate where the lower end of each bottom link passed through a separate hole cored through the plate, and was secured by a pin passed through the heads of the links, and resting in concave seats in the lower edges of the partitions. The plates and chains were then built in solidly with blocks of stone cut to fit each place, and thoroughly grouted so as to exclude water from the iron.

The portions of the chains and of the strands to a point 10 inches above bands (*d*), Figure I, Plate XXIV, were covered by masonry, and all the interstiees grouted.

III. *Arrangement of Top of Tower.*—On top of the tower is a heavy iron plate bedded in cement and covering the surface 8 feet square.

The upper surface of the plate has three ribs cast upon it parallel to the line of the cables. The two clear spaces between these ribs are each 2 feet wide, and the surfaces of the plates are planed. Each groove has a set of turned iron rollers 5 inches diameter, lying close together, and at right angles to the ribs. Each set of rollers supports a cast-iron saddle, whose underside is planed to rest on the rollers. The upper side of the saddle has a groove of semi-circular section in which the cable lies.

The spaces among the wires at the saddles, at the shoes and all the length of the cables were flushed with Spanish brown paint to keep out moisture.

IV. *Old Suspended Superstructure.*—The construction of the old work will be described under head of *Renewal of Suspended Superstructure.*

Inspection.

In February, 1877, Mr. Thomas C. Clarke, Member A. S. C. E., visited the bridge and caused an excavation to be made in the masonry covering the strands of the Canadian end of the lower north cable. On reaching the strands near the shoes, two or three of the outside wires were found to be corroded quite through, and a number of others were more or less corroded, and presented an appearance that was not very encouraging. In view of the possible extent that the deterioration might have reached, it was deemed best to reduce the weight of the trains crossing the bridge until a more thorough examination could be made.

Shortly afterward, Col. W. H. Paine, Member A. S. C. E., of the East River Bridge, went to Niagara, and proceeded to make a thorough examination. Men were set to work removing all the masonry from the strands and the first lengths of the chains. With a vernier scale he measured the elongation of the strands produced by a load on the bridge. He cut out some of the wires and tested them, both in tension and by bending them over the corner of a pair of sharp plyers.

Results of Tests.

1st. The elongation of the strains under a given load was found to be what the modulus of the wire would give if the section was full. Showing that the corrosion had not reduced the section of the strands so much as would be allowable, without weakening the cable as a whole, for the reason that the stress at the top of the tower exceeded that at the strands by about the strength of 40 wires.

2d. The results of the tensive tests were satisfactory, considering the fact that the specimens were more or less etched in places. Thus, while they showed an ultimate strength of about the same as the new wire was required to possess, the fracture was fine, perfectly fibrous, and the reduction good, yet the stretch was confined principally to the etched portion, where the specimen broke. This rendered a proper measurement difficult, inasmuch as the portion observed was several inches in length, while the part stretched would not exceed one-half inch.

It was interesting to note that even where a wire had its section nearly half eaten away, its ultimate strength would still be from two-thirds to three-fourths that of a whole wire, showing that the weaker portion of the metal were attacked first.

Repair of Wires.

On the 16th of March, 1877, the writer joined Col. Paine at Suspension Bridge to assist in examining the bridge and in repairing the defective wires.

After the strands were perfectly cleaned and the wire bands were removed, they were opened, and the inner wires were examined as far as it was possible to get at them, when they were found to be as clean and smooth as when first put in. After cutting out the defective portions of the outer wires, the next layer of wires, thus uncovered, where they bend around the shoe, were found to be clean and bright, proving that the only wires affected were the outer wires of the outside strands.

Near the band, which confined all the strands into one compact bundle, the outer wires were found to be slightly etched entirely around the cable. From that point toward the shoes the etching of the outer wires on the upper side decreased, while underneath it increased, till at the shoes the etching was mostly underneath. The evident cause of the corrosion was the elongation and contraction of the wires of the strands, due to loads passing upon and off from the bridge, thereby loosening the wires from the cement, thus admitting moisture, which gradually worked down to the lowest point. The portion of the cement among the strands would go and come with the strands themselves, thus excluding the moisture. Occasionally a lime stone spawl had been carelessly permitted to come into contact with the wires, when they were being covered, in which case it had caused a black spot, which, on being scraped, would reveal the outer wires corroded partly through.

While the examination was going on, the defective wires were cut out and new pieces were spliced in under a strain equal to that on the other wires.

The method of splicing in the new wires was as follows :

1st. The wire bands were removed from the strands and that portion of each wire, seriously corroded, was cut out. Each of the remaining ends were filed to a scarf and the side opposite the scarf, nicked with a set having transverse grooves across one end.

2d. A piece of new wire, a little longer than the piece removed, having one of its ends scarfed and nicked as above described, was spliced to one of the fixed ends by clamping the scarfs tightly with a small hand vice and then beginning at the middle of the splice it was served closely each way, to a point about one inch beyond the splice, with No. 20

annealed iron wire and fastened there by giving the wrapping wire a couple of "half hitches."

3d. A straining apparatus consisted of two pieces of iron (each about 3 feet long) hinged together at one end. The other ends were each provided with a hook and steel button, for the purpose of gripping the wire. About six inches from the button ends, a rod, with a thread cut nearly its whole length and a nut fitted to it, was arranged so as to draw the two ends towards each other. The new wire was then drawn as closely as possible by hand and one end of the strainer secured to it. The other end of the strainer was secured to the end of the old wire. Then by screwing on the nut the desired strain was applied and the new wire cut to the proper length. It was then released from the strainer and its end scarfed and nicked. The strainer was again applied and, when strained properly, the splice was completed by wrapping as before.

4th. The strain was measured by means of a spring balance. The balance was hitched to one of the sound wires at the middle point of that portion of the wire having no bands. Then pulling on the balance, the wire was deflected from a right line about 1¼ inches—the deflection of wire and strain indicated by the balance, being carefully noted, to be used as the standard for straining all the wires on that strand. When the strainer had strained the new wire to that extent, that with the same deflection, the balance read the same as before, it was then drawn enough further to make allowance for the slip of the splice.

After having completed the splice the strainer was removed and the strain tested by the balance. By exercising due care in making the splice in this manner, it has about the same strength as the weakest point of the whole wire.

The greatest number of wires thus renewed at either end of any one cable was sixty-five. As many of these were but slightly affected, it is not probable that any injury would have been done had the defective wires not been replaced.

In all cases where a wire was cut out, it immediately took the form of an arc of a circle with a diameter of about four feet. As this was the diameter of the coil previous to its going into the cable it was evident that the wires had never been injuriously strained.

Appointment of a Commission to Inspect the Bridge.

The Great Western Railway Company called for the appointment of a commission of engineers to inspect the condition of the bridge, according to the terms of their contract in leasing the railway floor.

The Bridge Directors selected Col. W. H. Paine, the Great Western chose Mr. T. C. Clarke, and these two gentlemen agreed upon Mr. Charles Macdonald (all members of the Am. Soc. Civ. Engr's) to complete the commission.

They arrived at the bridge April 17th. During that and the three following days, they made a very thorough examination of the cable strands and also of those portions of the chains that were accessible. Very close attention was given to the condition of the chains. Measurements were taken of the sections of all the upper links of each chain to ascertain the amount of metal in the bodies of the bars and of the heads each side of the pin, discovering the following conditions:

1st. The outer bars of each set had a rather greater section than any of the intermediate ones, and the total section of the bodies of the nine links of a chain was 86.625 square inches, the average width of each bar being 7 inches and the thicknes $1\frac{3}{8}$ inches.

2d. The diameter of the pin was slightly under $3\frac{1}{2}$ inches, or hardly five tenths the width of the body of the bar. The form of the head was approximately circular with a diameter of about 12 inches. The centre of the pin-hole, was in some instances so far toward the body of the bar from the centre of the head, as to leave the minimum section on each side of the eye less than half that of the body of the bar.

3d. Nearly all the pins in the shoes were found to be bent convex toward the cables, in some cases the convexity amounted to $\frac{5}{16}$ in. in the total bearing length.

Before leaving the bridge the Commission caused a train consisting of a switch engine and 20 loaded box cars, weighing 450 tons, to be run upon the bridge and had the curves of deflection taken for each position of the train in which the centre of gravity of the engine was at points 100 feet apart. (See plate XXIX, Fig. 1).

After due consideration the Commission reported substantially as follows:

The action of the wire portion of the cables, together with the results of tests of pieces of wire, indicate that when the work of mending the defective wires is completed the cables will be in good condition.

Regarding the anchor chains it was believed that the form of heads and size of pins were such that they would not withstand a strain greater than would be produced by 40 000 pounds per square inch of transverse section of the body of the link. Consequently while each cable was composed of 3 640 wires, each wire possessing an ultimate strength of 1 648 pounds, giving to it a total ultimate strength of (in round numbers) 6 000 000 pounds, the chain would not possess a greater ultimate strength than $86.625 \times 40\,000 = 3\,465\,000$ pounds, or 2 535 000 pounds less than that of the cable. Hence if the chain was reinforced sufficiently to make it equal the cable in strength, it would require an increase of section (estimated at 50 000 pounds per square inch) of 50 square inches area.

The report was accompanied with plans for this re-enforcement, and required that it should be made. It also suggested the renewal of the truss system, and submitted a general plan for an iron structure to replace the old wooden one.

Re-enforcement of Anchorage.

The writer, who was selected as engineer to execute the work of re-enforcement, arrived at Suspension Bridge September 13, 1877, with authority to make such alterations in the plans as circumstances might necessitate.

The data upon which the Commission's plan was prepared, aside from that ascertained by the inspection, were taken from the plates accompanying Mr. John A. Roebling's published report on Niagara Bridge. The plan was as follows :

1st. Four pits were to be sunk in the rock, one at the back end of each anchor wall. From each one of these pits two pairs of chains were to pass up to the surface of the rock from anchor plates secured at the bottom. From the surface of the rock the two middle chains were to pass in a vertical curve to a point at which the curve became tangent to the line of the upper cable and thence to the shoes, one on each side.

2d. Each shoe was to have a cast-iron block fitted in its opening, with one end concave, to fit against the pin. The other ends of all the blocks of a set were to project slightly beyond the forward ends of the shoes and have their ends faced in one plane at right angles to the centre line

of the cable at its intersection with the plane. Against these blocks were to rest the planed surfaces of two cross-bars. The ends of these bars were to project far enough at each side, and be rounded, to receive the ends of the two chains.

3d. The other two chains were to pass one on each side of the old wall, and in a vertical curve, till they were tangent to the line of the lower cable, and thence directly to the ends of cross bars arranged the same as those in the upper cable.

4th. The chains were to be of such length that when their ends were secured, as above described, one joint, *A*, of each, on the curved portion, should be a couple of inches nearer the centre of the curve than any of the other joints.

5th. After the chains were all in position, heat was to be applied to the chains to expand them sufficiently to allow of raising the low joints and blocking them with iron plates to such a height as would produce the proper stress upon the chains when cold.

6th. To measure the stress upon the chains, each of the bars forming the upper lengths of the chains was to be subjected, in a testing machine, to a tensive stress equal to the permanent stress it was to have when in position. The elongations corresponding to each bar, while under this stress, were to be carefully noted, and they were to be strained when in the work till they had the same elongation.

Changes of the Plan.

After uncovering the rock for the purpose of sinking the anchor pits, it was found that the old walls extended back further than was shown in the plates of Mr. Roebling's report, and that the line of the lower cable, produced, would enter the rock at a point nearly 30 feet from the new pit on the New York side and 12 feet on the Canada side. This would necessitate very expensive trenches, the excavation of which would be liable to disturb the old walls and perhaps the old anchorage of the upper cables.

To obviate this difficulty, the alteration was made, a description of which will be assisted by reference to Fig. 1, Plate XXIV. In this the pits were located the same as before, but were to be smaller. All the four chains in one pit were secured to a single anchor plate, by one pin, also by one pin in the first joint *C*. Beyond *C* each of the four chains was

independent of the others, but had the same curvature and rested on the same stone supports, to the point of tangency with the line of the upper cable, from which point two of the chains went to that cable. The other two passed, one on each side of the old upper cable chains and supports, in grooves cut in the masonry, and were secured to the lower cable. This arrangement required a bend in the chains to bring them on to the line of the lower cable. The consequent upward component of the stress was opposed by three pairs of stirrups attached to the projecting ends of three pins of the old chain, as shown at *a*, *b* and *c*.

The connection with the strands is made as by the Commission's plan, except that instead of the last links connecting directly with the cross-bars, a triangular link is interposed as shown by the dotted line in Fig. 2. The arrangement of the holes in this link is shown in Fig. 3. Its object is to cause a proper distribution of the stresses. There being three strands above and four below, the resultant of stress upon the entire chain was made to coincide with the centre line of the cable at this point, and to intersect, at a right angle, the line joining the points *e* and *f*, the centres of the cross-bars, at a distance from *e* equal to $\frac{1}{7}$ *ef*, while the centre of the pin connecting chain and link is at *d* on the centre line.

Application and Measurement of Stress.

These were made as before described in the case of the upper cable; but in that of the lower it was not necessary to apply heat, as the joint *A* could first be raised and blocked, after which the stress was applied by screwing down the nuts of the stirrups at *a*, *b* and *c*, until the scale indicated the proper elongation of the links.

The total sectional area of new chains for each cable is 50 square inches for that part from the strands to the upper point of curvature. From the latter point downward it diminishes till, at the anchor plate, it is 40 square inches.

The permanent stress upon the chain, or that from dead load alone, is 8 000 pounds per square inch.

The cross-bars are of crucible steel, of a pretty high grade, but thoroughly annealed. They are never subject to any shock.

Method of Doing the Work.

1st. *Sinking the Pits.*—In plan, the pits are 6 feet by 2 feet 6 inches.

On the New York side they were sunk to the depth of 17 feet; on the Canada side, to 23 feet. At the bottom they were chambered to 6 feet by 7 feet in plan, for the reception of anchor plates.

In sinking the pits, holes were first drilled along the four sides of each pit, as near together as was possible without having the drill break through the partition, and to nearly the designed depth of the pit. The core was then blasted out with light charges of dynamite, that being more local in its effect than gunpowder, and being less troublesome to use under water, of which we had an abundance, especially on the New York side.

The roofs of the chambers at the bottom of the pits were dressed and bush hammered to plane surfaces, sloping outward and downward, each way from the shaft. Just above the chambers notches were cut into the sides and ends of the pit (see Plate XXIV, Fig. 1).

2d. *Anchor Plates.*—These are of cast-iron, 5 feet 6 inches square, and strongly ribbed. Each plate has eight cavities cored into it, for the reception of the lower heads of the bottom links, enclosing them perfectly. One pin passes through all the eight links and all the partitions of the plate. The upper surface slopes outward and downward each way from the four sides of the rectangle occupied by the link openings. After the plate was placed in its proper position in the chamber it was solidly concreted underneath.

The stone blocks above the plate were cut to fit each place, as large as could be got in, and with thin joints. All vacant spaces were filled solidly with stone blocks set in cement, but no stone was permitted to come into contact with the links.

The shafts of the pits were not filled entirely until the stress was adjusted upon the chains.

21. *Taking Down the Old Walls.*—In removing the portion of the old wall preparatory to placing the chains, they were taken down nearly to the position of beds of the knuckle supports, and then the remaining portion was cut away with points and bush hammer to insure thin joints and solid beds.

The work of cutting the grooves, each side of the wall, for the reception of the lower cable chains, required extreme caution, especially where they passed alongside of and under the ends of the stone supports of the old chains. In the case of the south wall, on both sides of the river, these

old supports had been solidly bedded, but in both north walls we found large cavities under some of the supports. In such cases we were compelled to suspend cutting till the cavities could be solidly filled with cement mortar, and allowed to set, as of course the least settlement of any of these supports would destroy the adjustment of the cable, if it did not endanger the bridge.

After the new chains were adjusted the masonry was rebuilt, and both new and old chains covered and grouted solidly. But the wire strands are covered with brick houses properly supplied with means for drainage and ventilation. The roofs of the houses are provided with hatchways, the covers of which can readily be removed for purposes of inspection and painting.

Durability of the Work.

Referring to Fig. 1, Plate XXIV, it will be seen that the only manner in which the new chains can become slackened is from the settlement of the knuckle supports, and shrinkage of the joints around the anchor plates.

The portion of the old walls on which the new supports were placed was very firm, and, as the joints were all thin and the stones well bedded, there can be no danger of such settlement.

At the time the stress was applied the weather was warm, and the sun shining upon the chains, keeping them warmer than they can be again, covered with masonry as they now are. Hence the stress must have increased somewhat by covering them.

Again, one of the chains was left uncovered from D to F for two weeks, and the joint at E unsupported ; yet the joint only deflected half an inch out of the right line from D to F.

In concluding this account of the anchorage, it is proper to speak of the developments made in uncovering the old chains.

The curved portions of all the chains had settled forward toward the river and downward, leaving cavities between the cement and upper edges of the links and back of the pin ends. The cavities were largest at the upper joint, and nearly disappeared about the third joint down. The portion of the metal thus exposed had a thin coating of rust. On chipping off the cement forward of the pin ends, and at the sides of the links, the Spanish brown paint came off with the cement, and left the surface perfectly bright. This condition indicated that the masonry

covering of the chains had been put on before the weight of the bridge and cables had been applied.

The outside links of each set being slightly heavier than the intermediate ones, while they should have had but half the sectional area, would naturally elongate less under stress than the intermediate ones, and thus account for the bending of the pins before mentioned.

The pin holes of two of the outside links, which were accessible, were elongated, so as to leave an opening behind the pin of about $\frac{1}{8}$ inch. On this account I feared that some of the intermediate links might be in worse condition, but fortunately two adjacent heads of intermediate links were separated about $\frac{1}{4}$ inch, and by bending the sharpened point of a small wire, and inserting it, I could have felt the cavity, had there been one, but found no place large enough to receive the point. Hence I concluded that the other pin holes had been bored larger than they should have been, or that the bar had been short, and the eye filed or bored elliptical.

The removal of the masonry covering the old chains exposed all that portion of them about which there should be any doubt regarding their proper preservation, as the nearer we approach the anchor plates the less is the movement due to elongation produced by live loads, and the exposed links were carefully scraped and painted before re-covering them.

Renewal of the Suspended Superstructure.

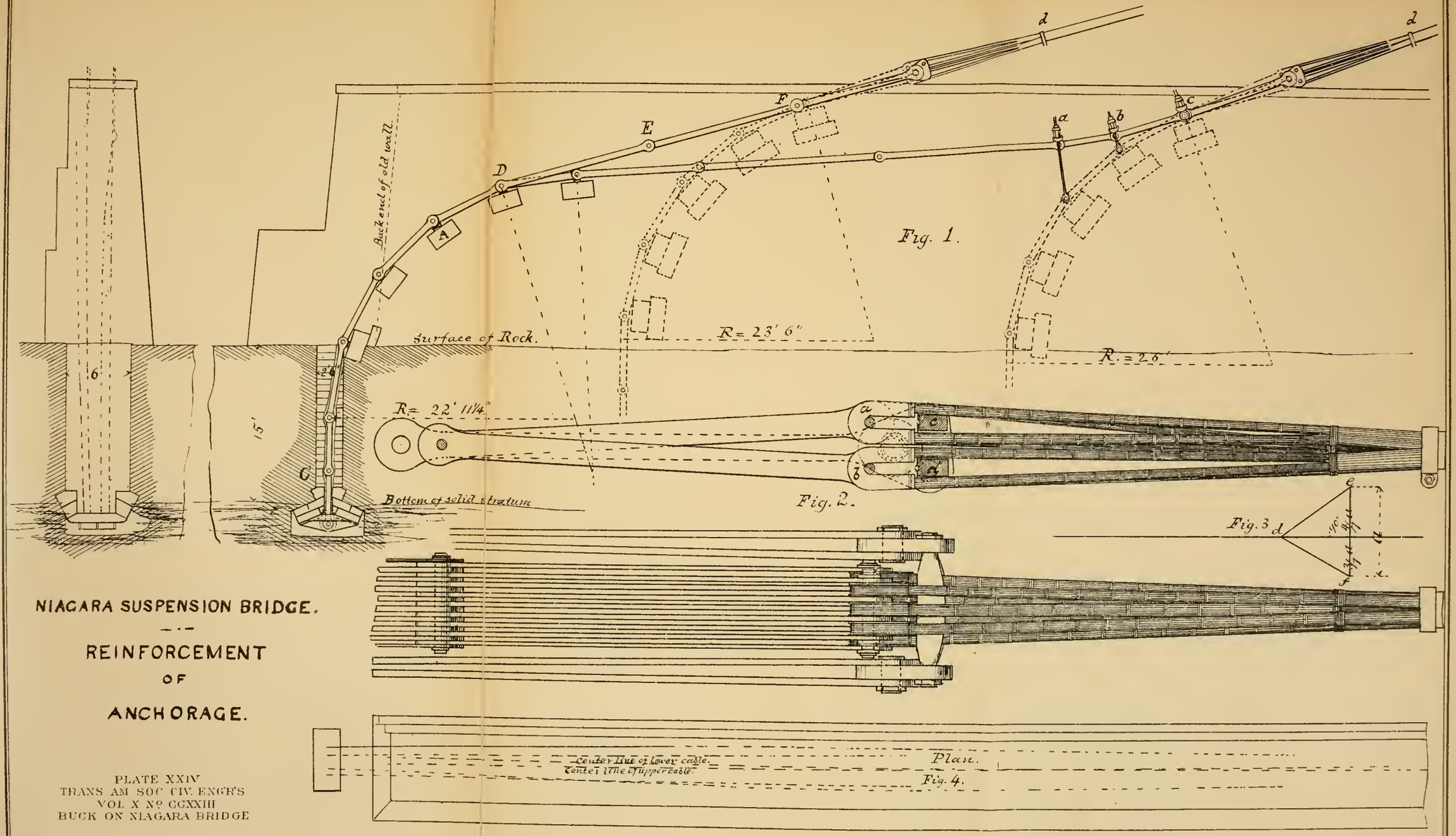
During the progress of the work on the anchorage, the writer made a careful examination of the suspended superstructure, both for the purpose of ascertaining its condition and to enable him to prepare some plan of either repairing it or of entirely renewing it with wood or iron.

The following in connection with Plate XXVII is a description of the suspended superstructure :

1st. *A Series of Transverse Bents.*—There was one bent at each five feet in the length of the bridge, or 161 bents in all. Each bent consisted of the following members :

a. Upper Floor Beams.—Each beam consisted of two pieces of 4 inches by 16 inches pine timber set on edge parallel, and 6 inches apart. These beams were 25 feet long.

b. Lower Floor Beams.—Each lower floor beam consisted of two pieces of 4 inches by 16 inches pine, 19 feet long, and two pieces of 6 inches by 13 inches pine, each 12 feet long. The 4 inches by 16 inches



NIAGARA SUSPENSION BRIDGE.

REINFORCEMENT OF ANCHORAGE.

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pieces were set on edge, and the two pieces of 6 inches by 13 inches were placed between them, with their ends abutting at the middle of the first two. They were strongly bolted together.

c. Posts.—There were two wooden posts, with a clear space between of 19 feet. Each post consisted of two pieces of 4 inches by 16 inches pine, separated by 4½ inches packing blocks. The upper ends of the posts were clamped between the two parts of the upper floor beam, and the tops flush with the upper edge of the beams. The feet of the posts rested on top of the 6 inches by 13 inches pieces of the lower beam, and were kept in place by white oak shoulder blocks spiked to beam and post on each side.

d. Knee Braces.—There was one knee brace of wood and one of iron from each post to the upper beam, and and one of iron from each post to the lower floor. The upper wooden brace from the inner face of the post, and the iron one from the outside. The lower brace was from the inner face of the post to the floor.

2d *Longitudinal members.*

a. Chords.—The upper chords were composed of two thicknesses of 2 inches by 12 inches white oak plank, one thickness in length of 5 feet, with the joints midway between the floor beams and resting at its middle portion on top of the floor beam and end of the post, while the other pieces were just long enough to go in between the floor beams and serve as a splice for the joint of the other piece. The two thicknesses were bolted together with eight one-half inch bolts to each panel. A double cast-iron angle washer for the end of the truss rod, was let into the top of the chord over each plate.

The lower chords were constructed in a similar manner, except that there was a 4 inches by 12 inches thickness of pine resting against the under side of the floor beam, then a 2 inches by 12 inches oak plank under this. On top, between the beams, was a 2½ inches by 12 inches pine plank. These were were bolted together with eight ½-inch diameter bolts, and had a double angle washer let into the under side, below each beam. This, together with the lower floor, was all the lower chord the bridge had at first, but as it was soon found to be insufficient, auxiliary chords, composed each, of two lines of timber were bolted to the under sides of the floor beams, and with a two inches space between it and the inner edge of the first lower chord. These timber chords were made continuous by scarfed and keyed splices, and were keyed to each other

at intervals of 2 feet 6 inches, with the splice of one at the middle of the length of the other. One of the timbers was 10 inches by 12 inches, and the other 10 inches by 8 inches. The stresses were transmitted to this chord by the transverse stiffness of the floor beams.

b. Track stringers.—There were two deep longitudinal track stringers, built partly above and partly below the upper floor beams. The portion above the beams was composed of 4 inches by 15 inches pine plank piled closely, broad sides horizontal, to a height above the beams of 2 feet 6 inches. The rails of the track were laid directly on the tops of these stringers.

The portion of each of the stringers below the floor beams was composed of two lines of pine timber made continuous by scarfed and keyed splices. That next the beam was 12 inches by 12 inches. The bottom one of 10 inches by 12 inches. The upper and lower portions of the stringers were secured together by four 1 inch diameter bolts passing from top to bottom in each panel.

c. Hand Rails.—Along each outside edge of the upper floor were two heavy hand rails, made on the Howe truss principle, the lower chord of which was under the ends of the upper floor beams.

d. Floor Planking.—The upper floor planking was in one course. That part between the track stringers being 4 inches thick. The remainder 2 inches thick. It was of pine, laid longitudinally with the bridge.

The lower floor was of two 2 inches thicknesses laid longitudinally, the first of pine and the second of oak. These were fastened to the floor beams with heavy wood screws.

e. Cornices.—To the ends of the upper and lower floor beams were secured strong cornices.

f. Truss Rods.—The truss rods of the middle four hundred feet were of 1¼ inches diameter round iron. The remainder were 1 inch in diameter. They formed quadruple triangulation in each direction, passing through the chords and angle washers where they were secured by a nut on each end.

3d.—*Suspenders.* Each bent was suspended to the cables by four 4½ inches circumference wire rope. Those from the lower cables were attached to the projecting ends of the lower floor beams, near the trusses by means of U shaped stirrups.

Those from the upper cables were attached to the upper floor beams,

one on each side, midway between the track and truss, secured to the beam by a screw, and with nut and washer below the beam.

4th. *Stays.*

a. Overflow Stays.—From the top of each tower, where their ends were made fast to the saddle, sixteen wire rope stays extended to various points of the upper and lower floors. The longest reached to a point 250 feet from the towers. They were 4½ inches in circumference.

b. Wind or River Stays.—Attached to each side of the lower floor at intervals of 25 feet for the whole length of the bridge, except 75 feet at each end were wind stays, whose other ends were anchored to large rocks on both sides of the river. There were fifty-six of them in all.

The above was the arrangement of the bridge previous to renewal. The upper floor had been rebuilt in 1873, but without altering the above arrangement.

The total suspended weight between the towers, including cables, stays, and water which the lower floors was so admirably adapted to retain, was but little less than 1 200 tons. The expense of keeping it in repair amounted to an average of about $6 000 per year.

Condition of the Structure.

At the time of examining the structure the old chords had become nearly worthless, to resist tension. Consequently, the floor beams had been compelled to transmit most of the stresses to the auxiliary chords below, and to the track stringers and hand rails above. This had caused the slipping of the joints of floor beams with posts and chords, water had worked in and by freezing had opened the fibre of the wood, causing it to decay very rapidly. The lower floor planking had ruts worn into it, so that it did not drain readily. The planking and tops of the beams had decayed so much as to be incapable of assisting the chords. Consequently, the latter had been broken in three or four places, and patched by bolting on planks.

The upper hand rails had been broken in several places, and the joints of the track stringers had many of them worked loose.

In short, there were very few tight joints in the structure. It had, consequently, become extremely flexible. When one-half of the bridge was loaded, had it not been for the overflow stays at the loaded end helping to sustain the load, and of the river stays at the opposite end helping to balance the load by holding their portion of the bridge down the

trusses would have been of very little use. Consequently, it was evident that any attempt to repair the structure would only result in the rapid destruction of the new work, and the more rapid destruction of the old.

Discussion of the Advisability of Rebuilding the Superstructure in Iron.

1st. It was of primary importance that whatever was done, the traffic over the bridge must not be delayed during the time occupied by making the change.

2d. Whatever material was used it must combine lightness with strength. The traffic over the bridge is continually increasing in weight, rendering it necessary on the one hand to provide a stronger superstructure, and on the other to decrease the weight, so as to increase the factor of safety.

In any bridge where the strain on each member is always in one direction, good sound timber can be made to answer a very good purpose, as when the joints once get settled to a firm bearing, there is afterwards but little movement, and they may, with proper care, be constructed to last a long time. Yet even the timber, suitable for this purpose, is becoming pretty expensive, and not easily obtained at that.

But in the case of a suspension bridge, where the stresses are constantly changing from tension to compression, or *vice versa* it is very difficult to form a wooden joint that will not move more or less. This causes it to wear, and water gets in, which accelerates destruction by softening the timber and causing rot.

Iron and steel is open to none of the above objections. If properly designed and constructed there is no reason why it should not last an indefinite period with proper care in keeping it painted.

Principles to be Observed in Designing such a Structure.

Although the object of the truss is to prevent too great undulation from the action of partial live loads and from wind, yet, to be economical, it must possess a degree of flexibility, for two reasons:

1st. That the cables being anchored at each end to the rock or other fixed material, there is a considerable change of deflection between extremes of temperature, amounting in the Niagara bridge, to about 2 feet.

The truss must consequently bend to accomodate itself to this motion, without subjecting the cables, or its own members, to too great stress in bending it.

2d. The greatest bending moment, to which the truss is liable is when a live load, of maximum intensity per running foot of bridge, beginning at one end, extended two-thirds of the length of the span. Now the greater the flexibility of the truss, the greater will be the deflection of the loaded portion. As the loaded portion deflects the curvature of the cable above it is increased, while the unloaded portion rises and hence the curvature of that portion is decreased. Consequently the dead load of the unloaded segment will balance that of the loaded segment as well as a portion of its live load. This is shown in Fig. 2, Plate XXVIII.

3d. If stays from the tops of the tower to different points of the floors are to be used, the trusses should be continuous from end to end and the middle point of their length should have as little longitudinal motion as possible, in order to make the stays effective at all temperatures. It is to be understood here that the only use of the stays is to assist the trusses. They are of no benefit to the cables.

The first and second of the above conditions are secured, by giving to the trusses such a depth as to allow of the required bending, without straining the metal of which they are made more than the desired maximum. The proper way is to first settle upon the greatest undulation admissible from partial loading, then give to the trusses a depth such that with the given deflection, or undulation, the metal will not be strained above the desired maximum per square inch of sectional area, after which that area must be sufficient to resist the maximum stress.

These undulations do not materially impede the passage of a train.

The third condition is satisfied by providing some automatic device to keep the interval between the ends of the trusses and the abutments as nearly constant as possible.

In the present case the depth of truss was approximately fixed by that of the old structure. But it was somewhat reduced by placing the lower chord on top of the lower floor beams, instead of below them, as in the old structure.

Preparation of Plans.

While engaged upon the work of re-enforcing the anchorage, I prepared plans for renewing the suspended superstructure in iron.

These plans having received Col. Roebling's approval, it was my wish to let the contract for furnishing the materials, immediately, in order that they might be manufactured and delivered during the fall and winter of 1878–9, ready for erection in the following spring. But the Board of Directors not being ready to commence upon it at that time, nothing further was then done about it.

During the winter of 1878–9 the question of using steel for the suspended superstructure of the East River Bridge came up. I then turned my attention to obtaining what information I could regarding the adaptability of that metal to the Niagara work.

I wish here to express my indebtedness to Col. W. H. Paine for many valuable notes and suggestions, on the use of steel for structural purposes, to the accumulation of which he had given close attention and much time.

There appeared to be no doubt that, for many of the members of the bridge, steel was admirably adapted.

1st. Its great strength admitted of a considerable decrease in weight of structure.

2d. Its modulus being but little greater than that of iron, it will, if given a maximum stress per square inch, proportionate to its strength, afford a given amount of flexibility with, at the same time, a greater depth of truss than could be allowed if iron was used.

This gives a greater moment of resistance to bending with a given chord section.

But the use of steel for structural purposes had not yet reached a stage at which all of the required shapes could be promptly and economically obtained—at least in this country.

Consequently my specifications were prepared to provide for the use of either iron, or steel, or a combination of both materials.

In the month of March, 1879, I was authorized by the Board of Directors of the Niagara Bridge Companies to submit general plans for renewal, to the before mentioned Commission of Engineers. The Commissions written approval was promptly given.

Several bridge manufacturing firms were invited to make tenders for

the contract. May 28, 1879, the bids were opened in the presence of the board and the contract was awarded to the Pittsburgh Bridge Co., of Pittsburgh, Pa.

By the terms of the specifications and contract, the materials were to be delivered at Suspension Bridge, ready for erection, August 1, 1879, and the erection to be completed by November 1, 1879.

The Pittsburgh Bridge Co.'s tender was for Bessemer steel and for iron.

Bessemer steel met the requirements of the specifications very well. The following is an extract of the specifications:

Quality of Materials Required.

Steel.—The steel must be of a quality such that in dimensions to be used it shall have an ultimate tensile strength of not less than 70,000 lbs. per square inch of sectional area, and an elastic limit of not less than 40 000 lbs. per square inch in tension or compression. Specimens bent cold through 90°, with an inner curvature not greater than one and a half diameters of the bar, must not show any cracks or flaws. When the specimens are tested in tension with a strain of 40,000 lbs. per square inch of section, their power for resisting shocks may be tested by striking them smartly with a hammer while under that strain, when they must not crack.

The specimens must elongate at least ten per cent. of their original length before rupture, and the ruptured sections must be reduced at least twenty per cent. of their original sections. Uniformity in modulus and ductility is to be secured as far as possible.

On reaching Pittsburgh, I made some tests of Bessemer steel. They gave very good results. But the only shapes to be obtained, in steel, were plates, angles and small channels. Consequently, the use of steel for the chords would require them to be built up of plates and angles riveted together. This would necessarily reduce the net section to a greater extent than if channels were used. Hence there could be no great advantage, in point of weight, by using steel, unless of a higher quality than that called for by the specifications.

I then found out at what increase of price per pound the steel, made under what was called the "Hay process," could be obtained, whose ultimate strength should not be less than 80 000 lbs. per square inch, and elastic limit of 48 000 lbs. It was then decided to use that material for

the chords, and Bessemer steel for the posts, lateral rods and track stringers. All other parts to be of iron.

The erection of the steel and iron work, and the riveting of their parts together, were included in the contract.

The cutting away to make room for the new work and the removal of the old material was to be done by the Suspension Bridge companies, and the whole work directed by their engineer.

Execution of the Work.

It soon became evident, on account of the unprecedented demand for iron and steel, which arose shortly after the contract was awarded, that it would be impossible to erect the work that fall. However, the work generally went forward in the shops when there was material on hand to enable them to work to advantage.

Every precaution was taken to render the materials and workmanship satisfactory. Tests were made upon specimens cut from every "blow," and then from specimens cut from the actual shapes rolled from each blow, and with no other preparation.

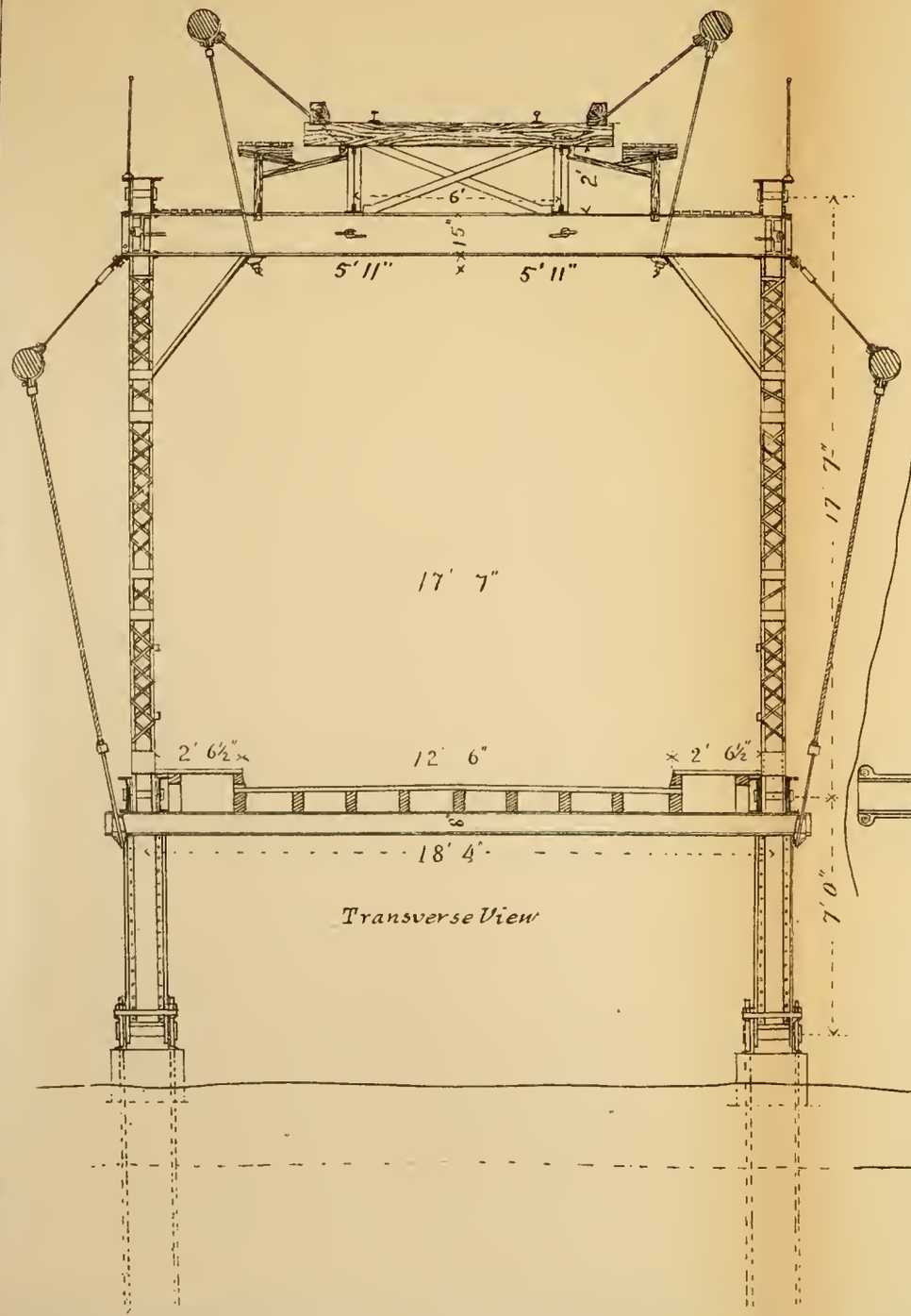
In building the chords, the angles were first punched with a punch about $\frac{1}{8}$ inch smaller than the rivet hole was to be when finished. They were then clamped to the plates in their proper positions, and a drill of proper size passed through both angle and plate, thus reaming the angle, and at same time drilling the plate, with the angle for a templet. Thus the holes were made to coincide exactly.

The rivets were all driven by pressure, steel parts having steel rivets.

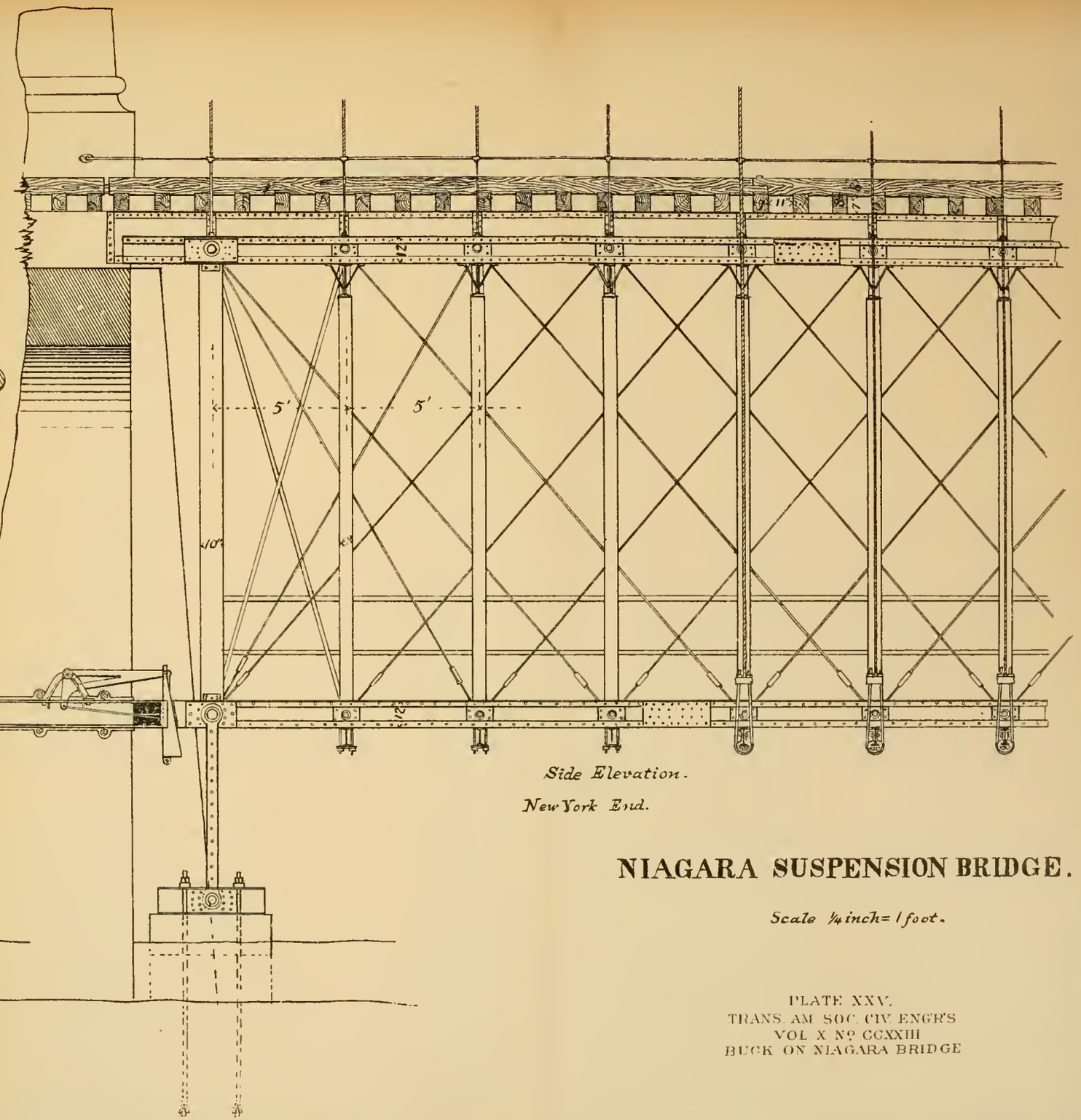
Before commencing the erection, an examination of the lower old floor beams was made to determine whether they would safely bear the increased weight, after having been weakened by the necessary notching, to which they would be subjected in placing the new work. They were found to have deteriorated so extensively that I decided to replace them by the new iron beams before commencing the work of erection proper.

The work of replacing these lower beams commenced April 13, 1880, at the middle of the bridge, and proceeded each way toward the ends. The lower cable suspenders were transferred to the ends of the new beams as rapidly as they were put in place.

As it progressed, the lower floor planking was taken up for a width of about three feet on each side ; a temporary wooden railing was put up on each side of the carriage way, leaving, for that purpose, a space nine



Transverse View



Side Elevation.

New York End.

NIAGARA SUSPENSION BRIDGE.

Scale ¼ inch = 1 foot.

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feet in width. The cornices above and below were stripped off, the rails forming the Erie broad gauge track were removed, and, in short, all materials not necessary to the stability of the structure were removed, in order to reduce the weight as much as possible. This part of the work was completed May 13, 1880. The weight thus removed was about 80 tons.

Erection.

The general arrangement and details of the new work are shown in Plates XXV. and XXVI.

Plate XXVII. shows the position of the new work with respect to the old.

The new superstructure is as wide as would admit of its being placed between the rods of the two old trusses. The bottoms of the new lower floor beams were placed level with those of the old. The tops of the new upper beams were level with the tops of the old, near their ends.

The new upper chords are three inches narrower than the lower ones, to admit of their being put in place without cutting away too much of the old chord.

The outer channel of the lower chord occupied the position of the foot of the inner half of the old post.

The work of erection began May 31, 1880, and proceeded as follows :

1st. Beginning at the middle of the bridge, five lengths of lower chord were placed in position on each side of the lower floor, to make room for which the inner piece of the old post was cut off and blocked to rest on top of the new chord. As the chord lengths were placed, their splices were riveted. The rivets for this purpose are of steel, and from $\frac{3}{4}$ inch to $\frac{7}{8}$ inch diameter. They were driven while hot, with 8 to 10 lb. sledges, which had the effect of upsetting the whole length of the rivet, and making it fill the hole very nearly as well as by pressure.

2d. Beginning at the middle again, one-half of each upper wooden floor beam was cut out. As soon as one of these was taken out, an iron beam was inserted by passing it between the parts of the track stringer, and, when in position, turning it on edge. As soon as an iron beam was in place, a pair of new posts were set up, the lower chord pins passed through chords, posts and truss-rod stubs. The heads of the posts were then placed under the ends of the new beam, and temporarily bolted to its lower flanges. The new beam was then firmly secured between the parts of the old track stringers by means of wooden wedges. The upper

suspenders were transferred to the new upper beams as rapidly as the beams were placed.

3d. As soon as twelve of these new bents were placed, three lengths of upper chord were laid on each side, their splices riveted and their flanges bolted to those of the upper beams.

4th. *New Truss Rods.*—These are in pairs and made adjustable by a sleeve nut with right and left hand threads. They extend from the top of the post to the feet of the third posts each way, forming triple intersection. While the erection was going on, but one rod was put in a place, to avoid overweight.

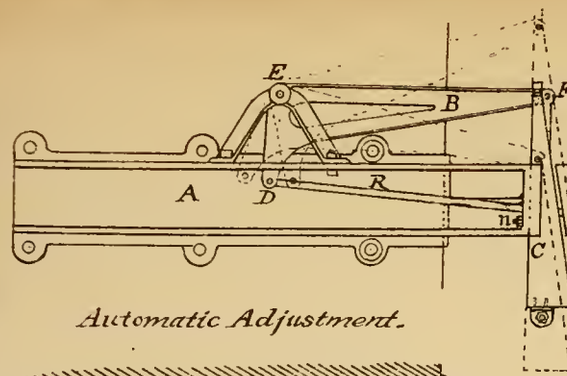
5th. When 150 feet of the new work was in place, the new chords at the end of that 150 feet were secured to the old by means of white oak clamps and keys.

6th. As soon as the clamps were secured, the work of removing the old materials was commenced at the middle of the bridge, and followed that of erecting the new, generally, with an interval of about 75 feet each way. The portion of the new work thus put in weighed about 1 100 pounds per foot run of bridge. Hence, there were seldom over 90 tons of new work overlapping the old. This was equivalent to about 150 tons of distributed load. Deducting the 80 tons saved by stripping the old bridge, we have left 70 tons as the probable extra dead load upon it. But as the trains had at the outset been limited to 190 tons, it is not probable that the total weight of live and dead load ever, materially, exceeded that of ordinary usage. While the above changes were in progress the work of replacing the lower floor planking was going forward each way from the middle.

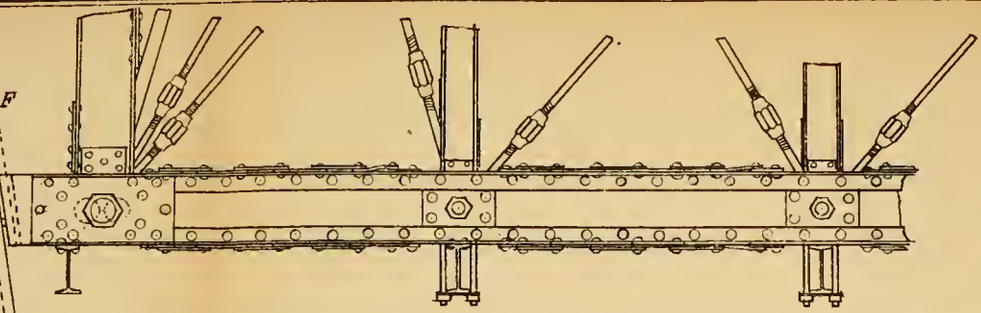
As the old planking was laid lengthwise, while that of the new was laid transversely, there was necessarily a gap between them, which was bridged over by a raised platform, under which the change was made, and which was moved along as the work progressed.

August 25th, all the above work and the riveting of its joints was completed to the ends. Up to that time there had been no interruption of traffic.

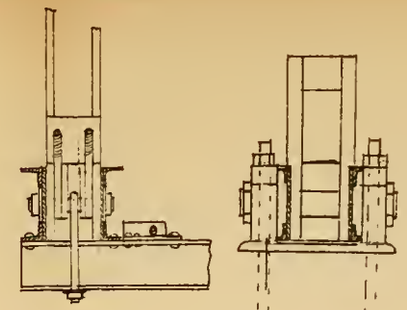
7th. *Replacing Track Stringers.*—This began at the middle and proceeded at the rate of 30 feet per day, each way, to the ends. The whole change was completed September 17, 1880.

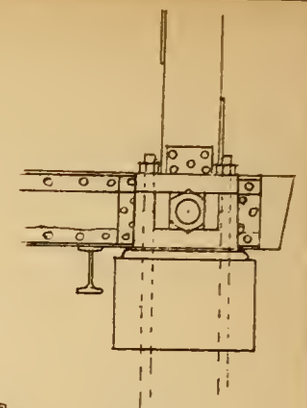


Automatic Adjustment.

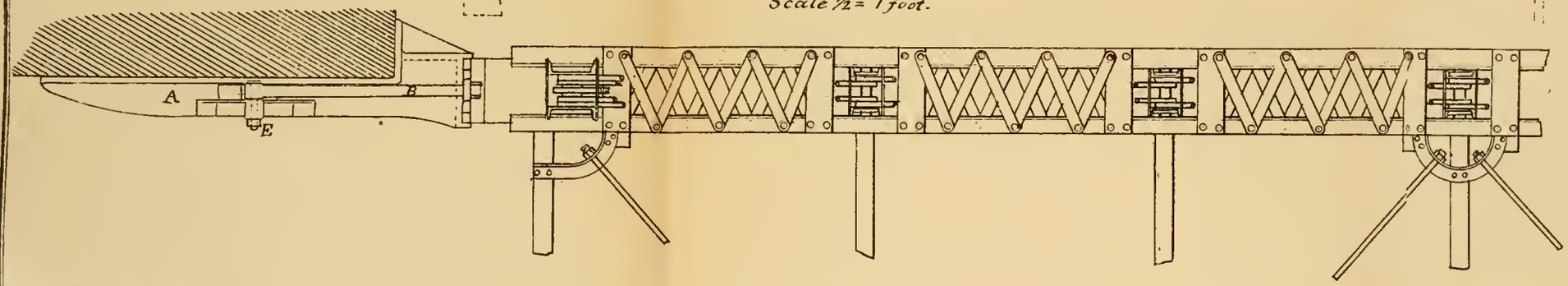


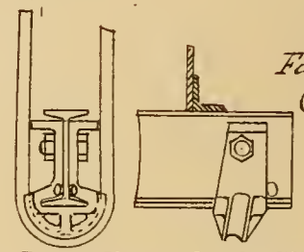
Details of Lower Chord.
Scale ½" = 1 foot.



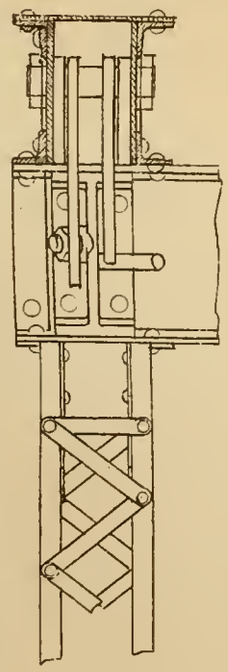


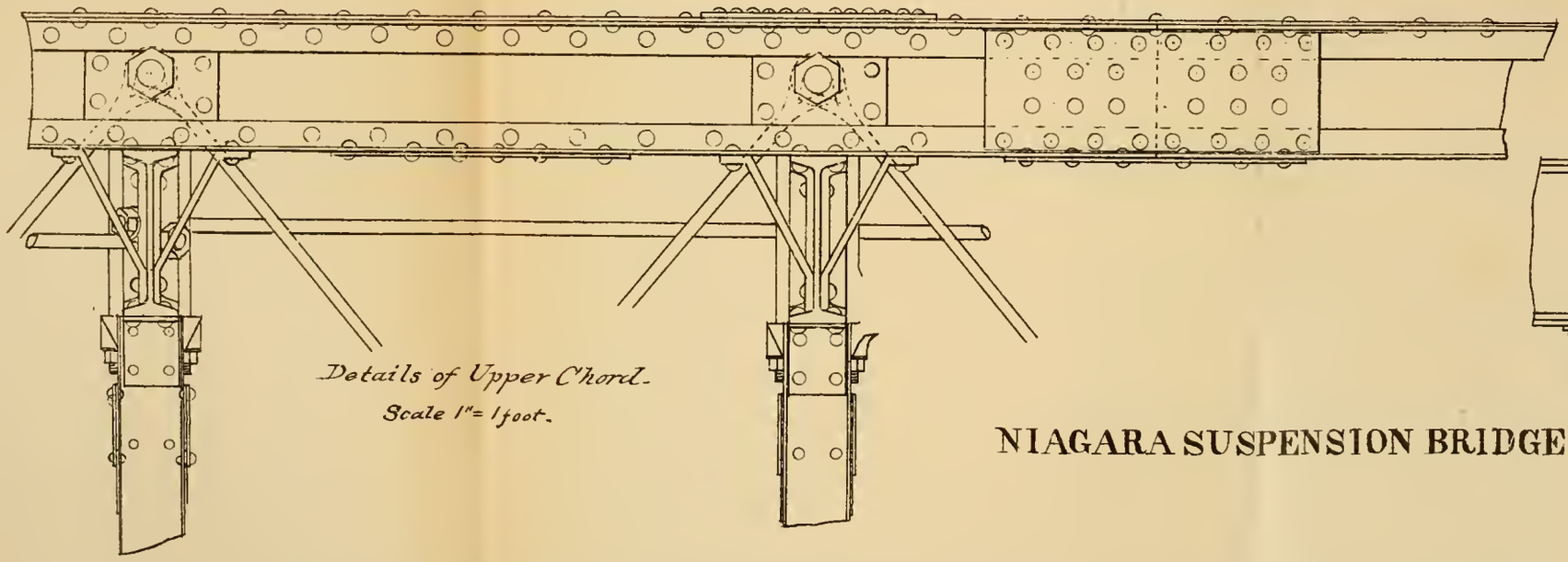
Fastening.
(Canada end).



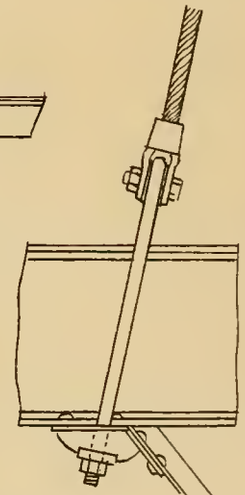


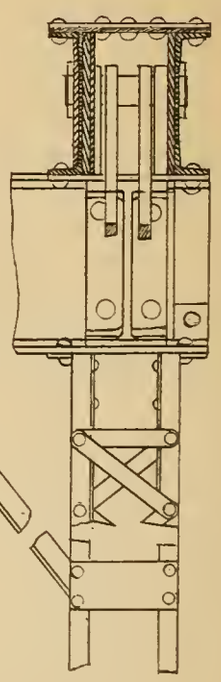
Lower Suspender Saddle.

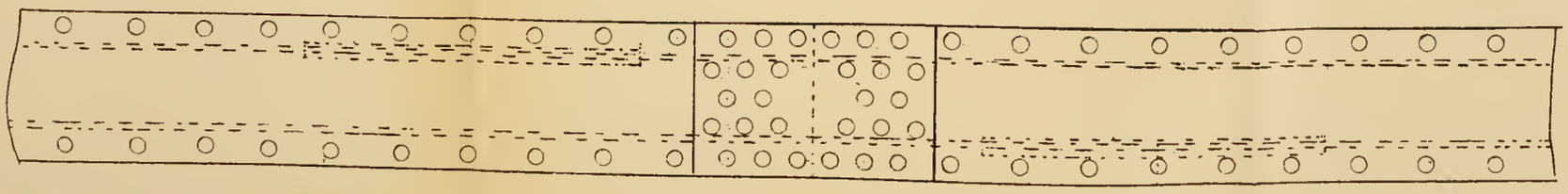




Details of Upper Chord.
Scale 1" = 1 foot.







NIAGARA SUSPENSION BRIDGE.

PLATE XXVI.
TRANS. AM. SOC. CIV. ENG'RS
VOL X Nº CCXXIII
BUCK ON NIAGARA BRIDGE

Adjustments.

The order and manner of making the adjustments were as follows :

1st. *The Camber.*—It was desirable to make the camber as nearly an arc of a circle as possible, at mean temperature. Consequently, the truss rods were all slackened in order to allow the cables to assume their natural curves under the dead load alone. The trusses were then brought to the calculated camber by screwing the suspenders up or down, as the case required. As this raising or lowering progressed, it was necessary to keep the truss rods slackened.

2d. *Stress on Suspenders.*—In making this adjustment, a hydraulic weighing machine was used. The method pursued was to make the machine the connecting link between a suspender and a beam, subject it to the proper stress, as shown by the index, then adjust three or four suspenders on either side of that having the machine attached, and judging of the stress by springing them with the hand, using that actually weighed as a standard. Of course, adjusting the adjacent suspenders would change the standard, which required to be constantly watched and kept to the proper tension. After adjusting all the suspenders in this manner, they were gone over again several times by trying the machine on an occasional suspender, till they were properly strained.

On account of the ends of the trusses being anchored to prevent vertical motion, it was necessary, on nearly approaching the ends, to gradually decrease the stress, till the end suspenders were reached, on which there was no stress.

3d. *Truss Rods*—At mean temperature, with the bridge unloaded, there should be no stress on the truss rods. Consequently, when the thermometer was at about 40° Fahr., the sleeve nuts on the rods were each screwed up to firm bearing, and then turned back one-half of a revolution, thus leaving the rods slack one-sixth of an inch. This gives the trusses a little more flexibility, decreasing the temperature stresses, and at the same time does not allow of more than the proper amount of undulation, as will be seen by an examination of the actual profiles of the floors for various positions of a test load of 357 tons (see Plate XXIX).

4th. *Over Floor Stays.*—The intention being to make the stays assist the trusses, when the live load, beginning at the end, extends about three hundred feet out, a train was moved out to the required position, and while there, the stays were screwed up to the proper stress.

In making the above adjustments, I was assisted by Mr. Frank W. Skinner (of the class of 1879, Cornell University), whom I found to be very faithful to his duties.

Present Arrangement of the Bridge.

The cables, with the exception of the anchorage and ends of the strands, remain as they were. Plates XXV and XXVI show the arrangement of the truss system, but the action of some of the parts will require explanation.

1st. End adjustment.

The object of this is to keep the middle point of the truss system as nearly stationary as possible for all temperatures.

As before stated, this is necessary, in such a suspension bridge as that at Niagara, when it is intended to use inclined stays from the tops of the towers to various points of the floors.

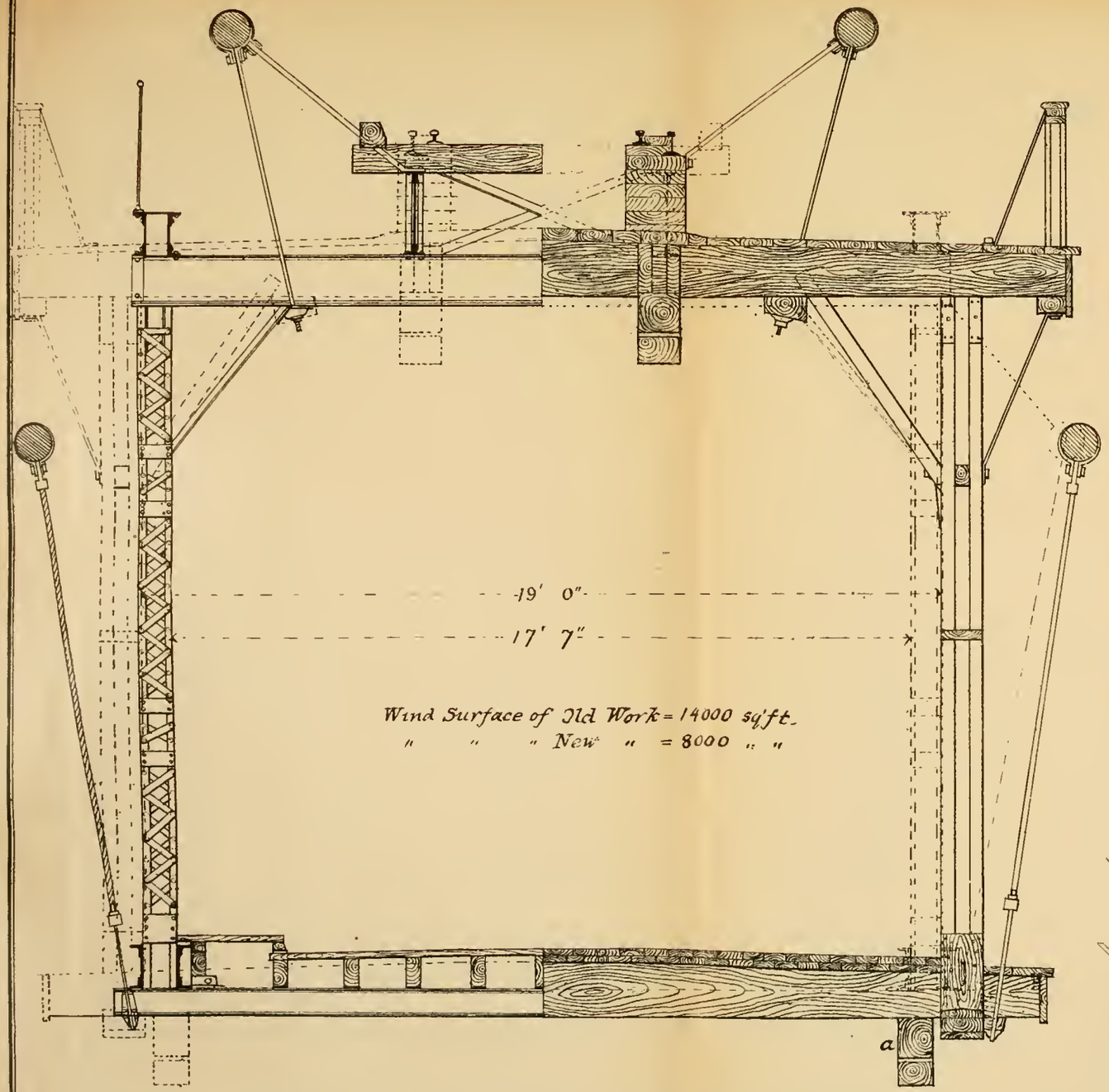
See Fig. 1, Plate XXVIII.

When a wooden truss is used, the point of attachment of the stay to the floor moves in a vertical direction with changes of temperature, further than the change of length of the stay can compensate for. Hence, if the stay is the right length in winter, it will be too short in summer. If an iron truss, with a slip joint in the middle, and ends fast to the towers, is used, the point of attachment will move in a line as *c*, *d*, and is in a worse condition than that where wood is used. But if the iron truss is continuous, and the middle kept from moving longitudinally, the point of attachment of the stay moves in the line *a*, *b*, and very nearly compensates for all temperatures.

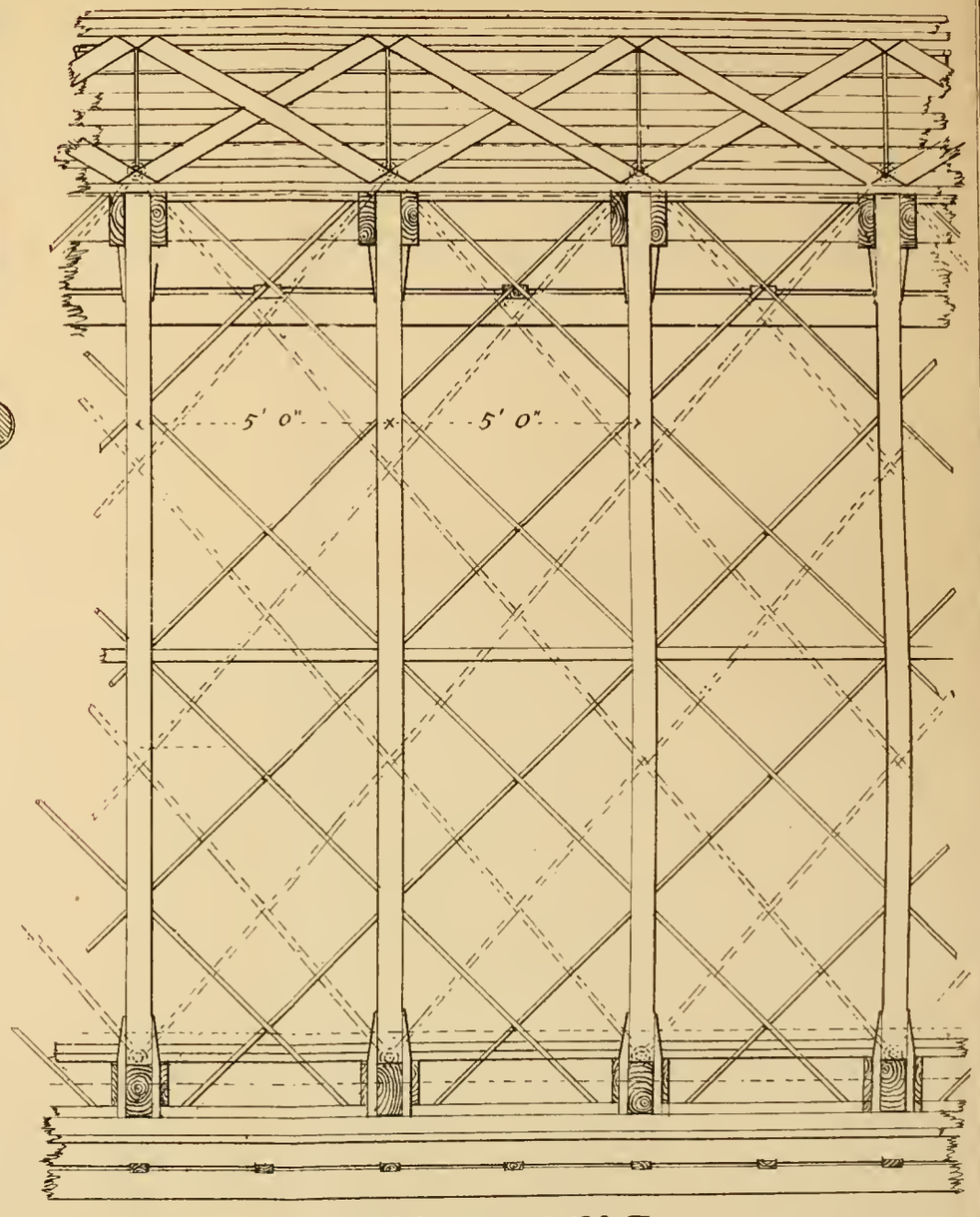
The same figure illustrates graphically the device that was used to keep the middle practically stationary.

The change in length of the truss between extremes of 120 degrees Fahr. temperature is about 8½ inches, or 4¼ inches at each end. See also Plate XXVI.

In each lower chord, extending from end to end of the bridge and lying loosely, are two ¾-inch iron rods. One end of one rod is fixed to the masonry of the tower, the other end is attached to *D* (Plate XXVI), the short arm of a lever, whose fulcrum is fixed to a casting *A*, firmly secured to the masonry of the tower. The long arm of the lever is three times the length of the short arm, and to its end *F*, is suspended a wedge *C*, having an inclination of 1 to 6 of its length. Then, while the end of



Transverse View showing relative positions of old and new work.



Side Elevation of Old Truss.

the truss moves 4¼ inches, the point *D* of the rod and end of the short arm of the lever moves 8½ inches, and the wedge is consequently moved vertically 25½ inches, or six times as far as the end of the truss moves longitudinally. The rod and chord expand or contract simultaneously, thus bringing a thicker portion of the wedge between the end of the chord and the abutment casting *A*, as the chord recedes. There is one of these wedges at each end of each lower chord. The wedges do not entirely fill the space between the chord and *A*, but have about ⅜ inch of "play" to prevent the wedges from getting caught. This interval of ⅜ inch is nearly constant for all temperatures. Should the wedges at one end of the bridge get caught at any time, the first engine that passes on to the other end will draw the truss away and release the wedge. The wedges never have caught yet, however, and there is very little liability of their doing so.

2d. *End Fastenings.*—The New York end of the truss is prevented from moving vertically by a hinged strut, Plate XXV. On the Canada end the rock came up too close to the lower chord, consequently, in place of the hinged strut, the end pins of the lower chord are provided with wrought-iron blocks, which are secured in slots of a casting, which allows of the longitudinal motion, but, the casting being anchored to the rock, will not allow vertical motion.

3d. *Upper Floor.*—The deep transverse beams of the upper floor, together with the deep longitudinal stringers distributing the weight over several beams, form a combination that deflects but very little under the weight of a train. Consequently, the knee braces, while they steady the bents transversely, do not spring the posts sidewise, as would be the case were the floor more flexible.

The stringers require to be strong and well spliced, as considerable of the stress that would otherwise come upon the upper chords, is transmitted through the transverse beams to the track stringers.

4th. *Lower Floor.*—The planking of the lower floor is laid transversely to the line of the bridge to allow it to dry off more readily. The narrow foot-walk on each side, not only make clean walks for pedestrians, but they serve to keep snow on the carriage way in winter and confine it to the space only that is necessary for sleighs.

5. *Lateral Stiffness.* As neither floor has any longitudinal planking to stiffen it, diagonal rods were introduced. The 56 wire rope stays are retained to resist the action of high winds, consequently, the only office

of the lateral diagonal rods is to prevent local derangement of the chord lines.

Strength of the Bridge.

The anchorage, cables and towers are the supporting members of the bridge, as before.

The strength of the anchorage has already been discussed.

Cables.

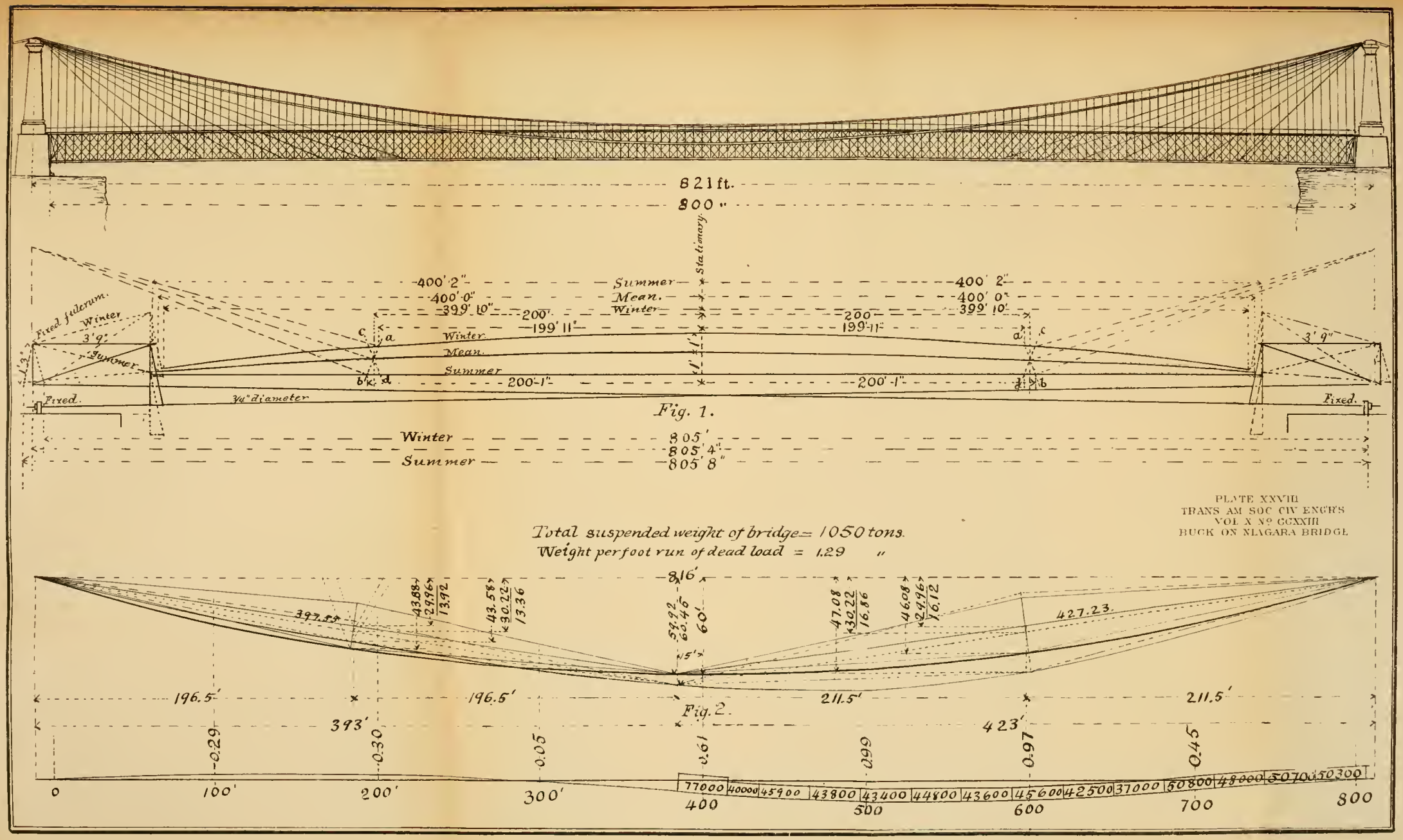
The number of wires in each cable is 3 640. The average ultimate strength of each wire was 1 648 pounds, giving for the strength of one cable 3 000 tons, or for the four cables 12 000 tons, in the direction of their length. There is no indication of deterioration of the wires, but suppose the wires not to have an ultimate strength of more than 1 511 pounds each, that would give for the four cables a strength of 11 000 tons.

The present total suspended weight of the bridge, between the towers, and including the cable, stays, &c., is 1 050 tons. Taking the maximum live load at 350 tons, makes in all 1 400 tons. The greatest stress upon the cables is at the towers, and equals $1400 \times 1.78 = 2492$ tons. Consequently, their factor of safety $= \frac{11\,000}{2\,492} = 4.41$. This is equivalent to a factor of 3 for the dead load and 8.65 for the live load.

Towers.

The maximum load on top of one tower is 700 tons. The section of the tower at the top is $8 \times 8 = 64$ feet. The pressure per square foot = 10.94 tons. The tower has a sufficient batter, so that for any section below the top, the 700 tons + the superincumbent weight of masonry, is less than 10.94 tons per square foot.

But there is one difficulty that must be constantly guarded against, viz.: The stone of which the tower is built is limestone, the surface of which "flakes off" on exposure to the atmosphere, frost, &c., though very strong where it is not exposed. If neglected, this would in time result in the destruction of the towers. It has heretofore been the custom to set new pieces into the faces of the towers when they were required. There appears to be no better method of meeting the difficulty.


821 ft.
800 "
Stationary.
400' 2"
Summer
400' 0"
Mean.
399' 10"
Winter
200'
199' 11"
Winter
Mean.
Summer
200' 1"
Fixed fulcrum.
Winter
3' 9"
Summer
Fixed.
3/4" diameter
Winter
805'
805' 4"
Summer
805' 8"
Fig. 1.
PLATE XXVIII
TRANS AM SOC CIV ENGR'S
VOL X Nº CCXXIII
BUCK ON NIAGARA BRIDGE
Total suspended weight of bridge = 1050 tons.
Weight per foot run of dead load = 1.29 "
816'
397.55
427.23
196.5'
211.5'
393'
423'
Fig. 2.
0.29
0.30
0.05
0.61
0.99
0.97
0.45
77000
40000
45900
43800
43400
44800
43600
45600
42500
37000
50800
48000
50700
50300
0
100'
200'
300'
400
500
600
700
800

There are 628 suspenders to sustain a maximum load of 1 025 tons, or 1.63 tons for each. In no case does the load exceed 2 tons on a suspender. They are of wire rope 4½ inches in circumference, and when new possessed an ultimate strength of 30 tons. Having to shorten some of them, I tested pieces of the wires occasionally by bending them over the corners of the sharp pliers. They bore the test as well as new wire.

The suspenders, as well as all the stays, are attached directly to the iron work of the suspended structure, which insures pemanency of adjustment.

Truss System.

This has been designated to have a factor of safety of 4 for a maximum live load of .8 ton per running foot, and covering a length or 450 feet. The section of each chord is 25 square inches, for a length of 200 feet each side of the middle. The section of the remaining portion, to each end, decreasing as the ordinates of a parabola, in the case of the upper chord, but in that of the lower chord, sufficient section to withstand the thrust of the stays, was continued to the ends. The factor of 4. did not consider the assistance of the stays.

Resistance to Action of Wind.

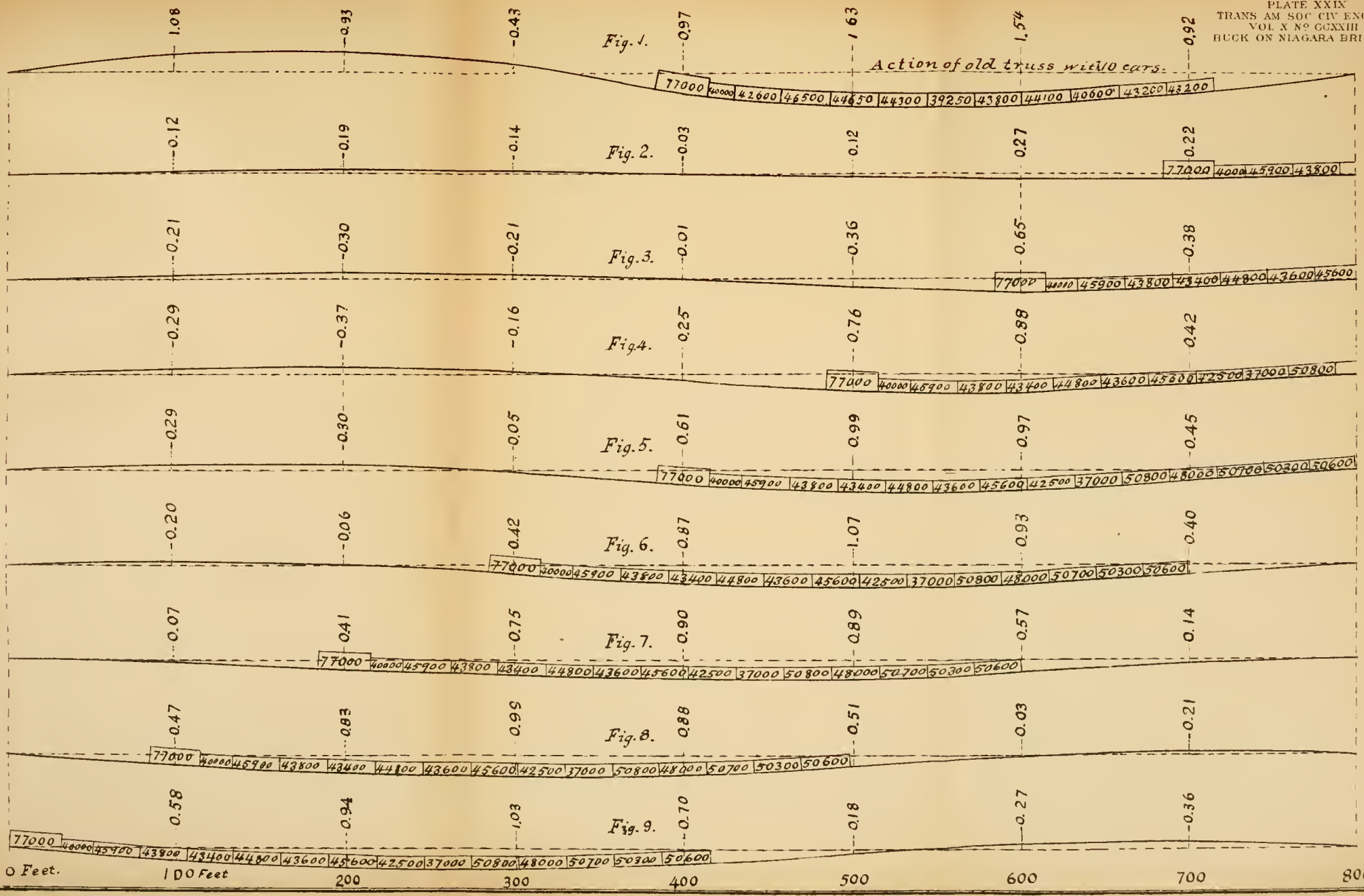
It is not necessary to insert here the calculation for wind pressure, for the reason that the bridge has the same wind stays as before, while the surface exposed is not much more than half what the old structure presented.

The effect of wind upon the bridge is not noticeable to a person standing upon it, for the reason that wind blowing in gusts does not affect it; while a high wind blowing steadily, in a direction transverse to the bridge, merely bends it three or four inches to leeward and holds it there while the wind continues.

In conclusion, I would remark, that in addition to the decrease of weight of suspended superstructure, the effect of live load upon the cables is considerably less than in the case of the old structure, for the following reasons:

1st. The load is distributed over a greater length.

2d. At about each quarter several stays pass vertically downward and are secured to rocks on the banks of the river. The old trusses were not strong enough to resist the bending effect of heavy train loads beginning at one end and extending to the middle of the bridge; consequently the unloaded quarter would rise sufficiently to cause a heavy tension on the vertical stays of that quarter, which stress must of course be added to the weight of the live load.


Action of old truss with 10 cars.
Fig. 1.
1.08 0.93 0.43 0.97 1.63 1.54 0.92
77000 40000 42600 46500 44650 44300 39250 43800 44100 40600 43200 43200
Fig. 2.
0.12 0.19 0.14 0.03 0.12 0.27 0.22
77000 40000 45900 43800
Fig. 3.
0.21 0.30 0.21 0.01 0.36 0.65 0.38
77000 40000 45900 43800 43400 44800 43600 45600
Fig. 4.
0.29 0.37 0.16 0.25 0.76 0.88 0.42
77000 40000 45900 43800 43400 44800 43600 45600 42500 37000 50800
Fig. 5.
0.29 0.30 0.05 0.61 0.99 0.97 0.45
77000 40000 45900 43800 43400 44800 43600 45600 42500 37000 50800 48000 50700 50300 50600
Fig. 6.
0.20 0.06 0.42 0.87 1.07 0.93 0.40
77000 40000 45900 43800 43400 44800 43600 45600 42500 37000 50800 48000 50700 50300 50600
Fig. 7.
0.07 0.41 0.75 0.90 0.89 0.57 0.14
77000 40000 45900 43800 43400 44800 43600 45600 42500 37000 50800 48000 50700 50300 50600
Fig. 8.
0.47 0.83 0.99 0.88 0.51 0.03 0.21
77000 40000 45900 43800 43400 44800 43600 45600 42500 37000 50800 48000 50700 50300 50600
Fig. 9.
0.58 0.94 1.03 0.70 0.18 0.27 0.36
77000 40000 45900 43800 43400 44800 43600 45600 42500 37000 50800 48000 50700 50300 50600
0 Feet.
100 Feet
200
300
400
500
600
700
800

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXXIV.

(Vol. X.—July, 1881.)

THE FLOW OF THE SUDBURY RIVER, MASSACHUSETTS, FOR THE YEARS 1875 TO 1879.

By ALPHONSE FTELEY, Member of the Society.

PRESENTED AT THE ANNUAL MEETING, NOVEMBER 3D, 1879.

DISCUSSION

On Rainfall and the Flow of Streams, by J. JAMES R. CROES, ASHBEL WELCH, JOSEPH P. DAVIS, FRANCIS COLLINGWOOD, CLEMENS HERSCHEL, GEORGE W. DRESSER, SAMUEL L. SMEDLEY, JULIUS E. HILGARD, THOMAS C. CLARKE, ALFRED G. COMPTON, OCTAVE CHANUTE, MARSHALL M. TIDD, WILLIAM R. HUTTON, CHARLES E. EMERY.

PAPER BY A. FTELEY.

The accompanying tables and diagrams, marked Plates XXX, XXXI, XXXII and XXXIII, are the results of daily gaugings made on Sudbury River for several years, in connection with the new works erected by the City of Boston for an additional supply of water.

The river, above the point where its waters are diverted, is formed by two principal affluents; the larger, draining about two-thirds of the gathering grounds, rises in a hilly district and flows afterwards through an open valley with extensive swampy areas; the other affluent flows

through a hilly district and, although draining a territory only one-half as extensive, it has sometimes, after heavy rains, a volume as great as the larger stream.

The whole water-shed controlled by the works covers seventy-eight square miles; a portion of it (from one-sixth to one-eighth) is covered with woods, the balance, with the exception of areas occupied by several villages, has a general agricultural character.

There being along the streams some small mill-ponds which are irregularly filled and emptied during the dry season, the daily flow at such times, below these ponds, does not represent fairly the yield of the water-shed; for this reason, the minimum flow has been shown in the tables for no less than one week.

The diagrams show the daily flow of the river for the years 1875 to 1878, inclusive, before the storage reservoirs were finished. In 1879 these basins, situated above the point where the water is diverted and measured, were filled for the first time, and the daily flow of the river, especially during the dry period, could not be ascertained with the same accuracy as it depended largely on the measurement of the level of water surfaces six hundred acres in area; it is for this reason that the diagram for 1879, Plate XXXIV, shows only the monthly averages of flow.

In 1874, before Sudbury River had been decided upon as a source of water supply, some observations were taken twice a week to form an idea of the flow; although the measurements were not made then by accurate methods, the results are sufficiently approximate to give an estimate of the volume flowing at the time of each observation. There were about ten observations taken every month, and the flow varied between the following limits, viz.:

In February,	from	109	to	480	million	gallons	per 24 hours.
" March	"	100	"	384	"	"	"
" April	"	95	"	256	"	"	"
" May	"	96	"	414	"	"	"
" June	"	32	"	380	"	"	"
" July	"	10	"	62	"	"	"
" August	"	8.7	"	82	"	"	"
" September	"	8	"	22	"	"	"
" October	"	8.1	"	25	"	"	"
" November	"	8.3	"	64	"	"	"
" December	"	24	"	62	"	"	"

An analysis of the data furnished will show the extent of water-shed, and the storage capacity which can be relied upon for furnishing a given daily supply of water, uniformly throughout the year, for a similar period and for a stream of similar description ; but longer and more severe droughts must be expected.

The water-shed controlled by the Sudbury River works is equal to seventy-eight square miles ; it has been calculated that with a complete system of storage reservoirs—eight in number—the supply would be equal to forty million gallons per day throughout the year. For the present, three storage reservoirs only, draining the same water shed, have been constructed; their joint capacity is equal to two thousand million gallons, and it was expected that the supply would be equal to twenty million gallons per day throughout the year, this computation, according to the best practice, was made on a liberal basis, but the experience of this season has shown that ample allowances must be made for extreme dry years.

The diagrams and tables explain themselves, but a brief description of the methods used for the gauging may be found sufficiently interesting to be mentioned. Plate XXXV shows the relative positions of the various points where the observations are taken.

The flow of the river is checked by a low timber dam *A*, built temporarily to direct the water into Farm Pond. From Farm Pond the water was originally taken from the city supply through a temporary channel *C*, of rectangular form made of sheet piling, and presenting a regular smooth surface. Since 1878, the water for the city supply has been taken through the new conduit *D*.

The level of Farm Pond is consequently under control, but its natural water shed, about one square mile, is included in the gathering grounds.

From the above it is seen that, in order to compute with accuracy the total yield of the river and of Farm Pond it is necessary to measure, first : The flow of water for the supply of the city through the channels *C* or *D*. Second : The storage in Farm Pond. Third : The flow of the river water wasted at the dam *A*.

The amount of water diverted for the city supply through the temporary channel *C* was computed from tables established by careful experiments made with floating tubes, and indicating the flow corre-

sponding to various heights of water in the channel, and to various inclinations of the water surface.

From year to year, or oftener, when found necessary, new experiments were made, and corrections rendered necessary by the slight changes in the shape of the bottom and sides of the channel, were entered in the tables.

The daily computations of volume were frequently checked by the readings of a current meter.

Since the abandonment of the temporary channel in 1878 the water used for the city supply has been measured in the conduit *D*, by the usual methods modified by local observations.

The storage of Farm Pond is computed daily by observations of its level, the water area, two hundred acres in extent, having been previously ascertained by actual survey.

The portion of the river flow which does not take place through Farm Pond is generally measured at the dam *A*.

The upper part of the dam, one hundred and twenty feet long, is made of movable flash-boards forming a well defined, level crest four inches in thickness ; when the dam is not in use, the river flows through a large flume, twenty feet wide, placed on one side of the dam with its bottom on the river bed. This flume is controlled by movable stop-planks.

With the exception of the periods when the river is swollen by freshets, when the gaugings are made elsewhere, the flow is measured either over the dam or through the side flume.

When the flow takes place over the dam it is computed by means of tables deduced from measurements made previously over a crest of similar construction. When the flow takes place through the flume it is measured in two ways ; if it does not exceed eighty million gallons per day, it is measured over three weirs placed across the flume in the stop-plank grooves ; if it exceeds that quantity, the volume is deduced, by observation of the depth of water in the flume, from tables established by numerous measurements made with a reliable current meter for all stages of the water ; the daily computations are frequently checked by use of the meter, and when slight discrepancies are observed between its readings and the tables, owing to small changes in the condition of the channel below the dam, corrections are made accordingly. From what precedes it may be seen that all the observations necessary for the

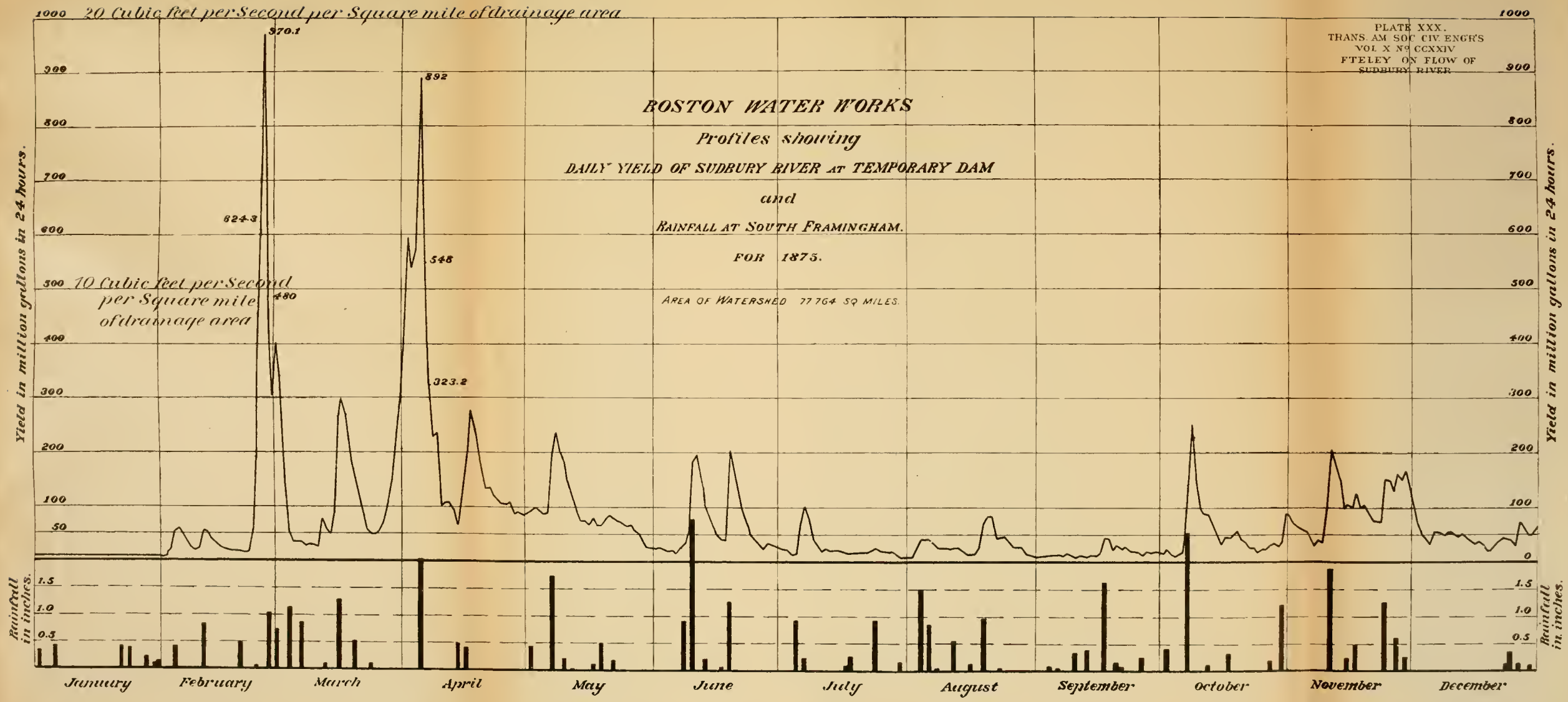


PLATE XXX.
TRANS. AM SOC CIV. ENG'RS
VOL X Nº CCXXIV
FTELEY ON FLOW OF
SUDBURY RIVER
BOSTON WATER WORKS
Profiles showing
DAILY YIELD OF SUDBURY RIVER AT TEMPORARY DAM
and
RAINFALL AT SOUTH FRAMINGHAM.
FOR 1875.
AREA OF WATERSHED 77.764 SQ MILES.
20 Cubic feet per Second per Square mile of drainage area
10 Cubic feet per Second per Square mile of drainage area
Yield in million gallons in 24 hours.
Rainfall in inches.
1000
900
800
700
600
500
400
300
200
100
50
0
1.5
1.0
0.5
370.1
624.3
480
892
548
323.2
January
February
March
April
May
June
July
August
September
October
November
December

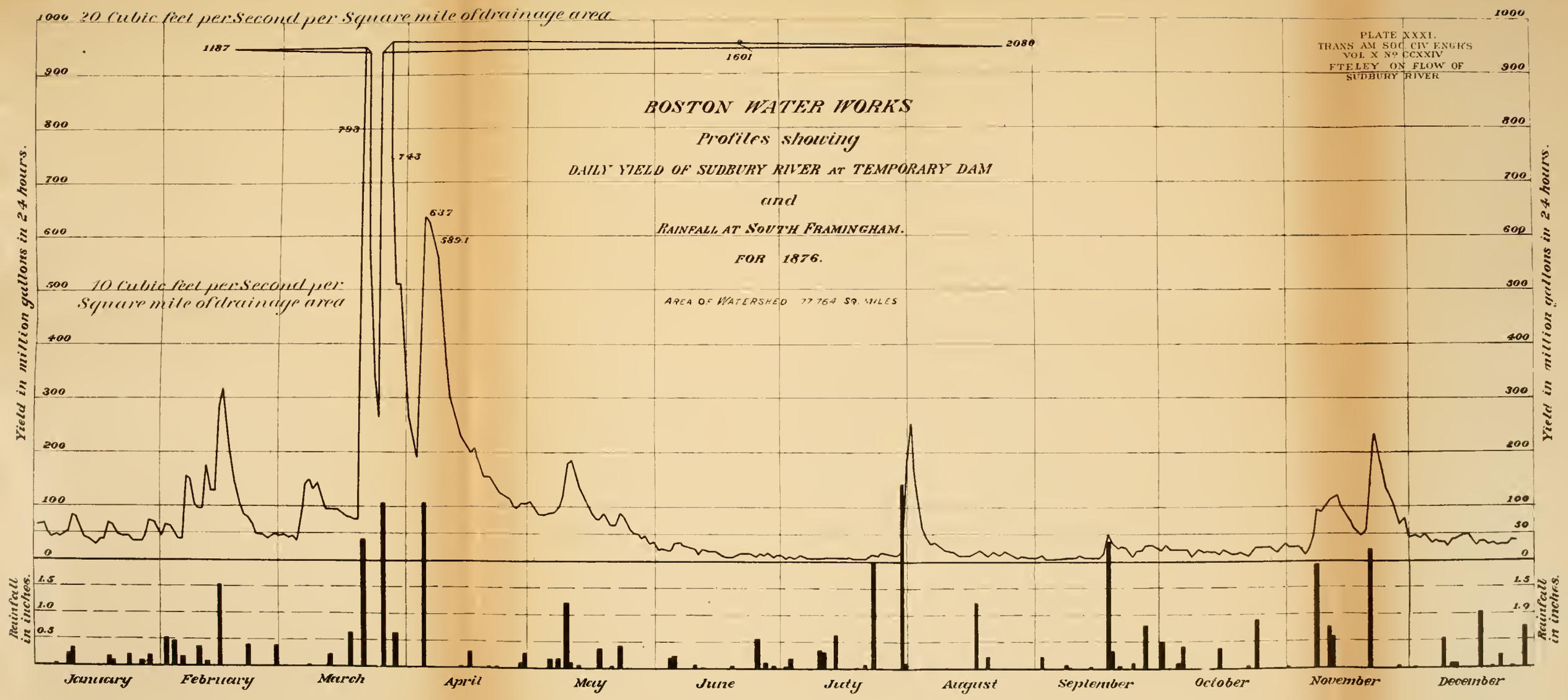


PLATE XXXI.
TRANS AM SOC CIV ENGRS
VOL X No CCXXIV
FTELEY ON FLOW OF
SUDBURY RIVER
BOSTON WATER WORKS
Profiles showing
DAILY YIELD OF SUDBURY RIVER AT TEMPORARY DAM
and
RAINFALL AT SOUTH FRAMINGHAM.
FOR 1876.
AREA OF WATERSHED 77.764 SQ. MILES
20 Cubic feet per Second per Square mile of drainage area
10 Cubic feet per Second per Square mile of drainage area
1187
793
743
637
589.1
1601
2080
Yield in million gallons in 24 hours.
Rainfall in inches.
January
February
March
April
May
June
July
August
September
October
November
December

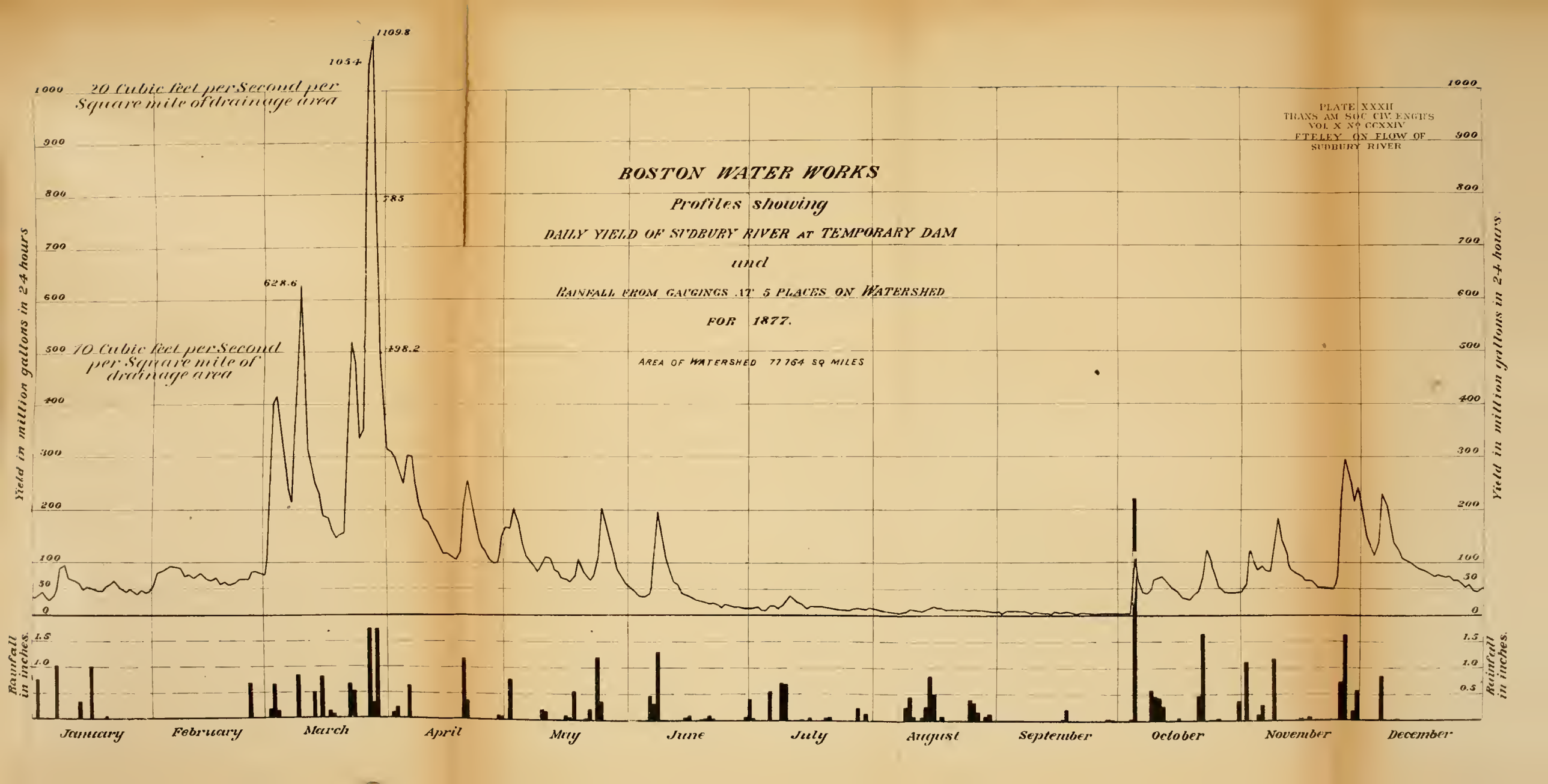


PLATE XXXII
TRANS AM SOC CIV ENGTS
VOL X Nº CCXXIV
FTELEY ON FLOW OF
SUDBURY RIVER
BOSTON WATER WORKS
Profiles showing
DAILY YIELD OF SUDBURY RIVER AT TEMPORARY DAM
and
RAINFALL FROM GAUGINGS AT 5 PLACES ON WATERSHED
FOR 1877.
AREA OF WATERSHED 77.764 SQ MILES
20 Cubic feet per Second per Square mile of drainage area
10 Cubic feet per Second per Square mile of drainage area
1109.8
1054
785
628.6
498.2
Yield in million gallons in 24 hours
Rainfall in inches.
January
February
March
April
May
June
July
August
September
October
November
December

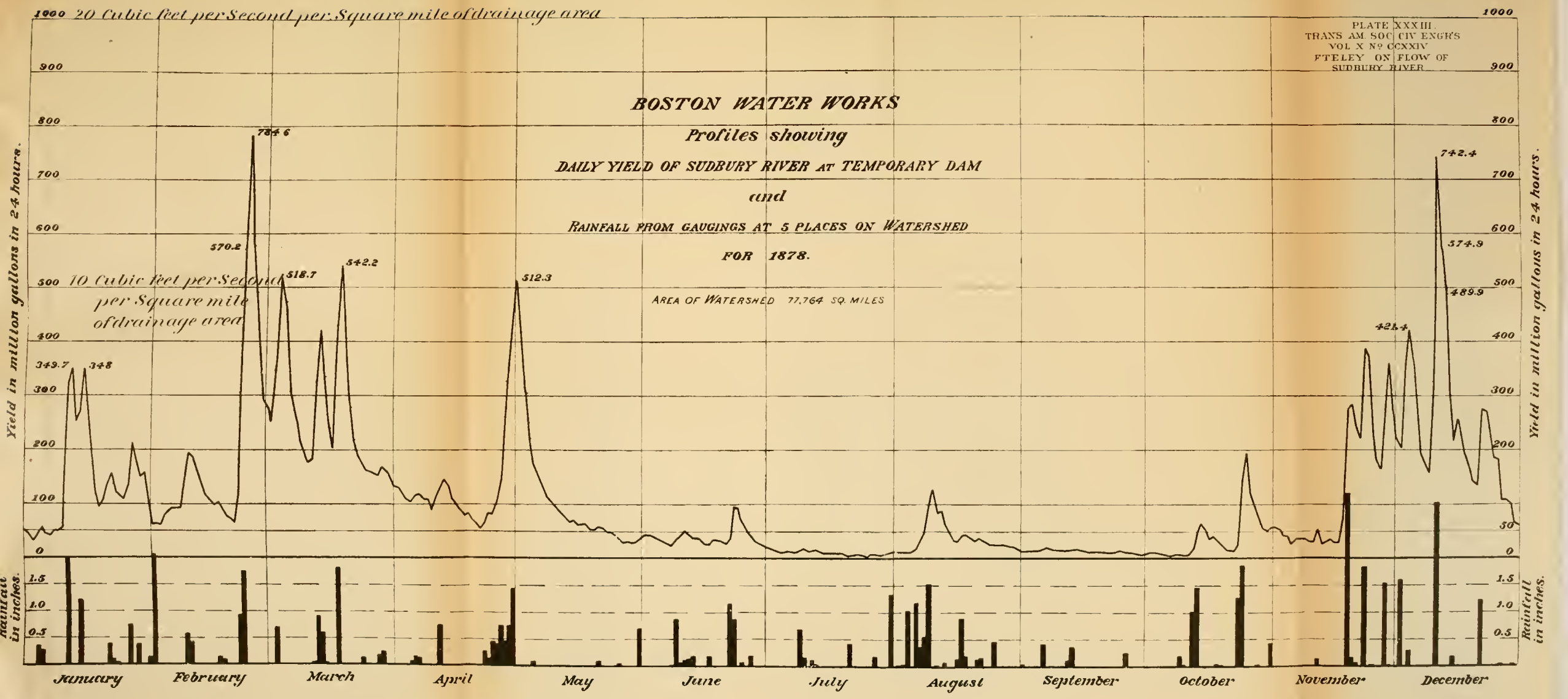


PLATE XXXIII
TRANS. AM. SOC. CIV. ENG'RS
VOL. X. No. CCXXIV
FTELEY ON FLOW OF
SUDBURY RIVER
BOSTON WATER WORKS
Profiles showing
DAILY YIELD OF SUDBURY RIVER AT TEMPORARY DAM
and
RAINFALL FROM GAUGINGS AT 5 PLACES ON WATERSHED
FOR 1878.
AREA OF WATERSHED 77.764 SQ. MILES
20 Cubic feet per Second per Square mile of drainage area
10 Cubic feet per Second per Square mile of drainage area
Yield in million gallons in 24 hours.
Rainfall in inches.
1000
900
800
700
600
500
400
300
200
100
0
1.5
1.0
0.5
349.7
348
570.2
784.6
518.7
542.2
512.3
421.4
742.4
574.9
489.9
January
February
March
April
May
June
July
August
September
October
November
December

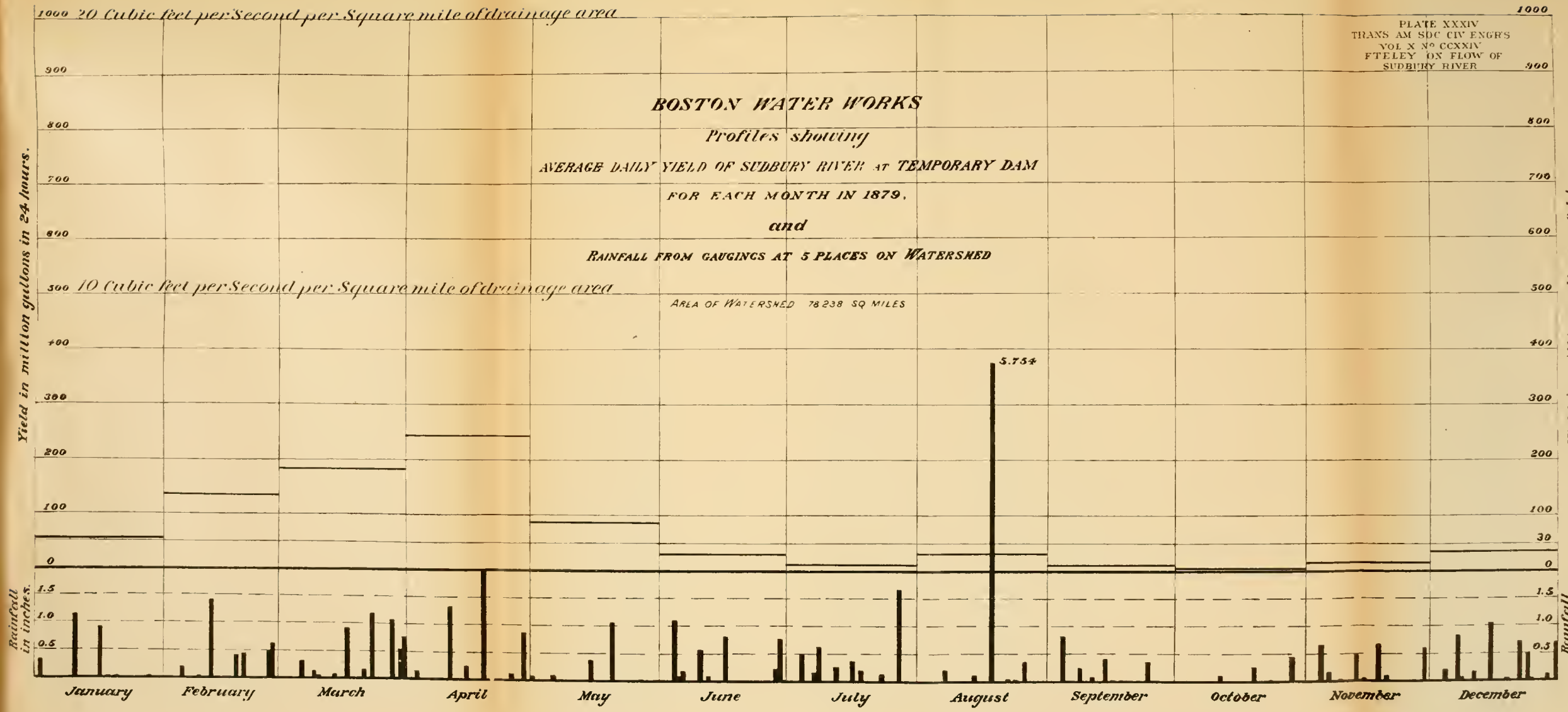


PLATE XXXIV
TRANS AM SOC CIV ENGRS
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FTELEY ON FLOW OF
SUDBURY RIVER
BOSTON WATER WORKS
Profiles showing
AVERAGE DAILY YIELD OF SUDBURY RIVER AT TEMPORARY DAM
FOR EACH MONTH IN 1879,
and
RAINFALL FROM GAUGINGS AT 5 PLACES ON WATERSHED
AREA OF WATERSHED 78.238 SQ MILES
20 Cubic feet per Second per Square mile of drainage area
10 Cubic feet per Second per Square mile of drainage area
Yield in million gallons in 24 hours.
Rainfall in inches.
5.754
1000
900
800
700
600
500
400
300
200
100
30
0
1.5
1.0
0.5
January
February
March
April
May
June
July
August
September
October
November
December

measurement of the water at the dam, whether it is allowed to flow over it or through the side flume, are reduced to the registering of the water level.

The levels, which in 1875 were taken three times a day, were afterwards ascertained by continuous diagrams recorded by a self-registering float. The float is contained in a box which can be connected, according to the way the water is made to flow, either with the still water above the dam or with the flume at its side. Plate XXXVI.

An endless sheet of paper, moving between guides on a horizontal table, advances at the rate of one foot in twenty-four hours under the action of the brass roll *A*, which is moved by clock work.

The float *O*, is suspended by a slender metallic thread from the pulley *C*; the slack of the thread is taken by the weight *D*. The motion of the pulley, when acted upon by the float, is transmitted by the wheels *E F* to the horizontal bar *G*, which carries the pencil *H*, and moves on two small rolls. The range of the variations of level at the dam being about eight feet, it is often necessary, in order to remain within the limits of the paper, to reduce considerably the motion of the pencil; it is for this reason that the main pulley *C* has four grooves of different diameters. When the largest diameter is used, the motion of the pencil is one-eighth of that of the float; when the smallest is used, the pencil moves as the float; the largest has been used almost exclusively. The difference of temperature has no perceptible effect on the length of the wire, and the loss of motion in the transmission of the movements of the float does not cause any appreciable error. In the winter a kerosene lamp suspended in the float-box and a small kerosene stove kept burning in the room containing the apparatus, are sufficient to prevent freezing.

In order to render the diagram independent from the side motion of the endless paper, a stationary pencil *K* records a line which represents constantly a given height of the float ascertained by actual measurement of the level of the water, and the variations of level indicated by the diagram are measured by the distances between the two pencil lines.

The diagrams, when taken from the apparatus, are divided by vertical lines into sections, for each of which the average ordinate is established by planimeter measurement. These sections vary in length according to the frequency and magnitude of the changes in the water level, being made very short when the irregularities are frequent and large, or extending the whole length of a day or more if the level

remains nearly constant. The error due to this method of computing the average ordinates is small when the sections into which the the diagrams are divided are judiciously determined.

When the variations of the flow are large, or when the flow is to be turned to or from Farm Pond, some considerable time is needed to place or remove the flash boards on the stop-plank; but the recording apparatus requires very little attention.

The office work necessary for computing the flow is also inconsiderable at ordinary times.

The accompanying Plate XXXVII, showing the level of the water for two days, has been prepared at a scale of one-fifth of the working diagrams for the purpose of illustrating the work of the apparatus. It represents within a small compass a considerable range of variations.

As the water at the dam stands at very different levels, according to its mode of flowing, the line traced by the movable pencil as it rises or falls does not give, at first sight, any correct idea of the increase or decrease of the flow. It indicates simply the height at which the water stands and the depth of water (whether over the crest of the weirs or in the flume) from which the volume is computed.

The line *O O*, traced by the stationary pencil, represents on the diagram elevation 146 above base, and is approximately straight, the side motion of the endless paper being small.

At the beginning of the diagram, on February 12th, the flow of the river is supposed small (3 700 000 gallons in twenty-four hours), and it passes over one weir occupying one-third of the width of the flume. At 6 P. M., there being an indication of an increase of flow, owing to a rise in the temperature, the three weirs are put in, occupying the whole width of the flume, and the level falls. The flow continues to increase, and at 2 P. M. on the 13th, after a rain, it is found necessary to remove all obstacles in the flume; as a consequence, the diagram shows a sudden fall of the water surface; the volume of the river keeps on increasing, but commences to fall towards the end of the day.

All this time the water has been wasted, but at 12 M. of the 15th it becomes necessary to turn the water into Farm Pond. The stop-planks are put in the flume, and for one hour the water rises behind the dam. Then it overflows, and from that time to the 21st the flow takes place over the crest of the dam.

PLATE XXXV
TRANS. AM. SOC. CIV. ENG'RS
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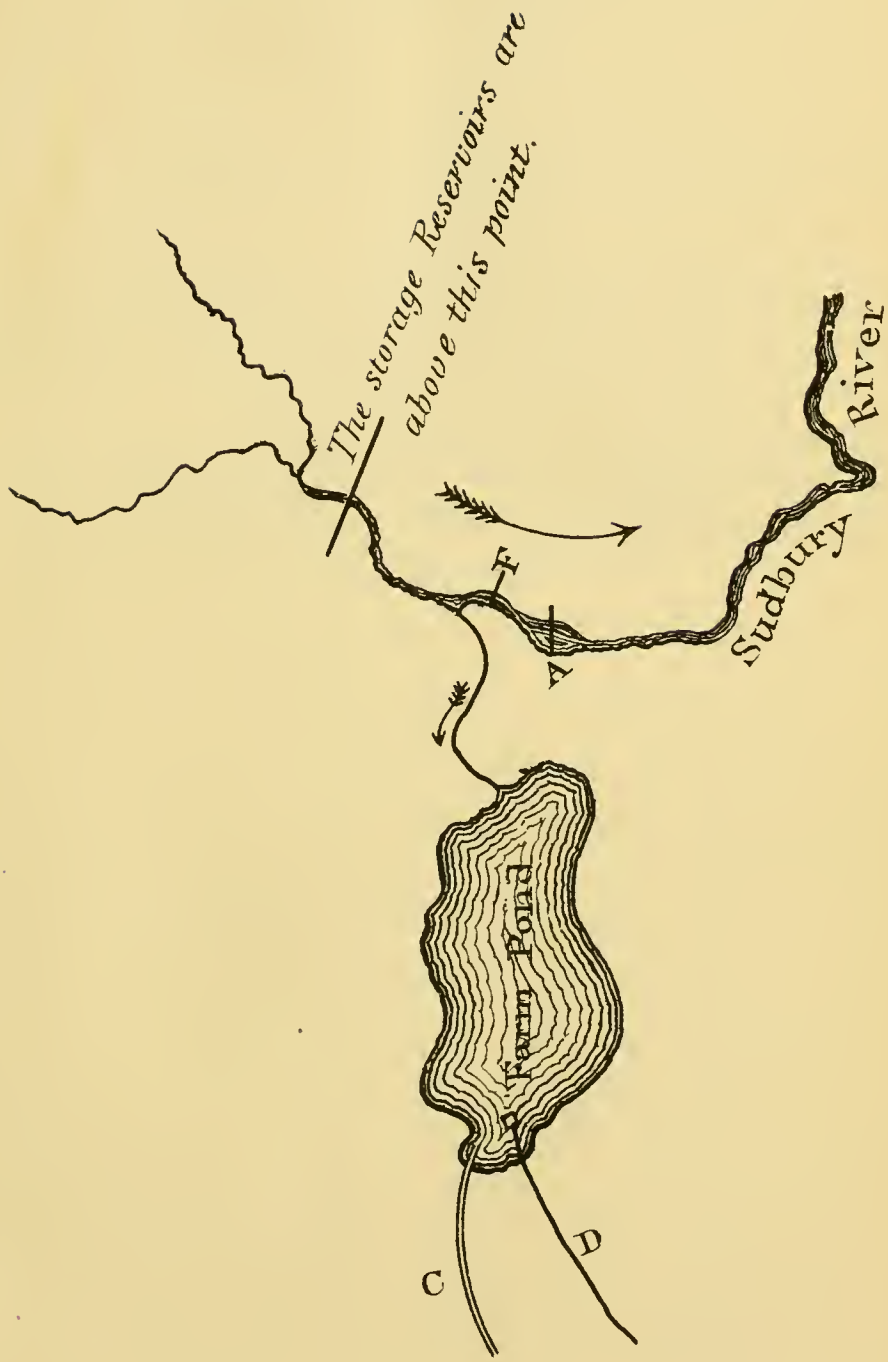
FTELEY ON FLOW OF
SUDBURY RIVER



The ordinates in the diagram indicate the sections into which it is divided to compute the flow.

When the volume of the river is so large that the flash-boards of the dam have to be removed to avoid damage from flowage, the flow cannot be gauged with accuracy by the same methods, and the volume is then measured from time to time with a current meter at a point *F* (Plate XXXV) of the stream where it is enclosed at the sides by smooth vertical walls, and where the bottom is formed by a plank floor securely fastened to the bed of the stream. A foot bridge thrown across the river at that point enables the observer to take the measurements with ease.

The flow of the river has been measured several times simultaneously at the dam by the methods previously described, and at the foot bridge by current meter, and the results have always been found to agree closely.

At the end of March, 1876, the flow was unusually large, and none of the gauging apparatus could be used, the results recorded for that time were calculated from several observations taken a little higher up on the river at mill dams and road bridges.

YIELD OF SUDBURY RIVER.

TABLE SHOWING YIELD, RAINFALL, AND THE PROPORTION OF THE RAINFALL REPRESENTED BY THE YIELD.

Month.	1875.				
	Total Yield of Sudbury River. Gallons.	Average Daily Yield. Gallons.	Rainfall. Inches.	Amount of Rainfall represented by flow in River.	
				Inches.	Percentage of total Rainfall.
January	248 000 000	8 000 000	2.42	0.184	7.60%
February	3 257 800 000	116 350 000	3.15	2.411	76.54 "
March	3 867 200 000	124 748 400	3.74	2.862	76.52 "
April	7 113 200 000	237 106 700	3.23	5.263	162.94 "
May	2 863 100 000	92 358 100	3.56	2.119	59.52 "
June	2 029 100 000	67 636 700	6.24	1.501	24.05 "
July	774 700 000	24 990 300	3.57	0.573	16.05 "
August	954 000 000	30 774 200	5.53	0.706	12.77 "
September	483 800 000	16 126 700	3.43	0.358	10.44 "
October	1 557 500 000	50 241 900	4.85	1.152	23.75 "
November	3 038 000 000	101 266 700	4.83	2.248	46.54 "
December	1 407 300 000	45 396 800	0.94	1.041	110.74 "
	27 593 700 000	75 599 200	45.49	20.418	44.88 "

Month.	1876.				
	Total Yield of Sudbury River. Gallons.	Average Daily Yield. Gallons.	Rainfall. Inches.	Amount of Rainfall represented by flow in River.	
				Inches.	Percentage of total Rainfall.
January	1 550 300 000	50 009 700	1.83	1.147	62.68%
February	3 084 500 000	106 362 100	4.21	2.282	54.20 "
March	10 691 100 000	344 874 200	7.43	7.911	106.47 "
April	7 680 400 000	256 013 300	4.197	5.683	135.41 "
May	2 744 000 000	88 516 100	2.763	2.031	73.51 "
June	517 500 000	17 250 000	2.040	0.383	18.77 "
July	441 100 000	14 229 000	9.134	0.326	3.57 "
August	976 900 000	31 512 900	1.720	0.723	42.03 "
September	430 200 000	14 340 000	4.614	0.318	6.89 "
October	563 000 000	18 161 300	2.241	0.417	18.61 "
November	2 537 800 000	84 593 300	5.764	1.878	32.58 "
December	1 093 100 000	35 261 300	3.620	0.809	22.35 "
	32 309 900 000	88 278 400	49.563	23.908	48.24 "

PLATE XXXVI
TRANS. AM SOC. CIV. ENG'RS
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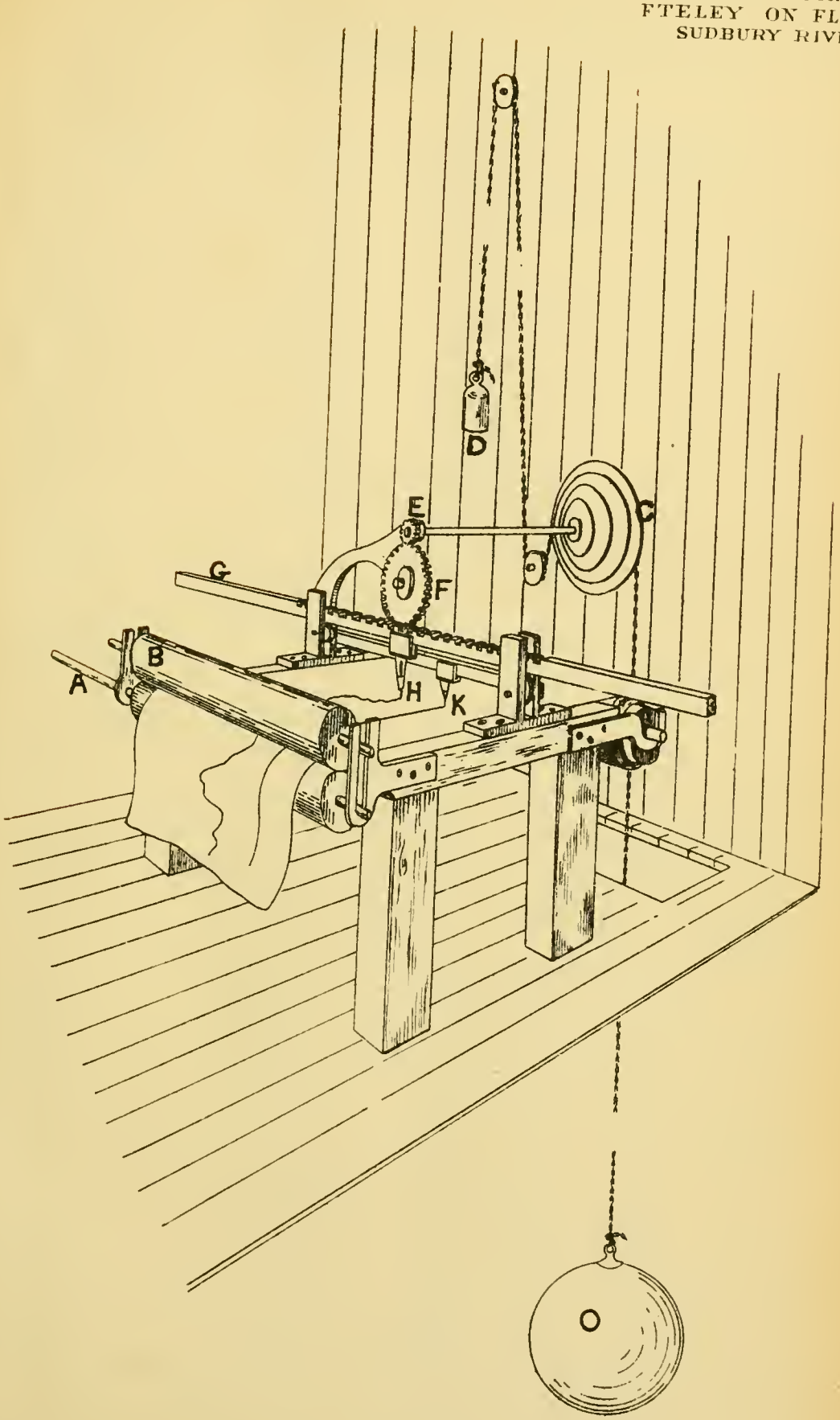
FTELEY ON FLOW OF
SUDBURY RIVER



YIELD OF SUDBURY RIVER.

TABLE SHOWING YIELD, RAINFALL, AND THE PROPORTION OF THE RAINFALL REPRESENTED BY THE YIELD.

Month.	1877.				
	Total Yield of Sudbury River. Gallons.	Average Daily Yield. Gallons.	Rainfall. Inches.	Amount of Rainfall represented by flow in River.	
				Inches.	Percentage of total Rainfall.
January	1 586 900 000	51 190 300	3.216	1.174	36.50%
February	2 066 900 000	73 817 900	0.739	1.529	206.99 "
March	11 604 100 000	374 325 800	8.357	8.586	102.74 "
April	5 584 100 000	186 136 700	3.435	4.132	120.29 "
May	3 354 200 000	108 200 000	3.702	2.482	67.04 "
June	1 393 000 000	46 433 300	2.425	1.031	42.52 "
July	486 060 000	15 679 400	2.951	0.360	12.20 "
August	291 890 000	9 415 800	3.682	0.216	5.87 "
September	139 000 000	4 633 300	0.323	0.103	31.89 "
October	1 522 400 000	49 109 700	8.515	1.127	13.24 "
November	3 307 300 000	110 243 300	5.803	2.447	42.17 "
December	3 108 900 000	100 287 100	0.870	2.300	264.37 "
	34 444 750 000	94 369 200	44.018	25.487	57.90 "

Month.	1878.				
	Total Yield of Sudbury River. Gallons.	Average Daily Yield. Gallons.	Rainfall. Inches.	Amount of Rainfall represented by flow in River.	
				Inches.	Percentage of total Rainfall.
January	4 362 100 000	140 712 900	5.632	3.228	57.32%
February	5 367 900 000	191 710 700	5.973	3.972	66.50 "
March	8 454 400 000	272 722 600	4.689	6.256	133.42 "
April	3 793 200 000	126 440 000	5.790	2.807	48.48 "
May	3 361 600 000	108 438 700	0.956	2.487	260.15 "
June	1 179 800 000	39 326 700	3.884	0.873	22.48 "
July	309 500 000	9 983 900	2.971	0.229	7.71 "
August	1 146 300 000	36 997 400	6.937	0.848	12.22 "
September	375 100 000	12 503 300	1.291	0.277	21.46 "
October	1 244 300 000	40 138 700	6.417	0.921	14.35 "
November	3 949 000 000	131 633 300	7.024	2.922	41.60 "
December	7 658 800 000	247 058 100	6.367	5.667	89.01 "
	41 202 000 000	112 882 200	57.931	30.487	52.63 "

YIELD OF SUDBURY RIVER.

TABLE SHOWING YIELD, RAINFALL, AND THE PROPORTION OF THE RAINFALL REPRESENTED BY THE YIELD.

MONTH.	1879.				
	Total Yield of Sudbury River. Gallons.	Average Daily Yield. Gallons.	Rainfall. Inches.	Amount of Rainfall represented by flow in River.	
				Inches.	Percentage of total Rainfall.
January	1 698 200 000	54 780 600	2.478	1.249	50.40%
February	3 747 900 000	133 853 600	3.562	2.756	77.37 "
March	5 651 400 000	182 303 200	5.140	4.156	80.86 "
April	7 313 700 000	243 790 000	4.716	5.379	114.06 "
May	2 701 400 000	87 141 900	1.579	1.987	125.84 "
June	970 200 000	32 340 000	3.789	0.713	18.82 "
July	381 700 000	12 312 900	3.933	0.281	7.14 "
August	958 300 000	30 912 900	6.509	0.705	10.83 "
September	330 300 000	11 010 000	1.878	0.243	12 94 "
October	171 500 000	5 532 300	0.809	0.126	15.57 "
November	482 500 000	16 083 300	2.682	0.355	13.24 "
December	1 121 800 000	36 187 100	4.344	0.825	18.99 "
	25 528 900 000	69 942 200	41.419	18.775	45.33 "

MONTH.	1880.				
	Total Yield of Sudbury River. Gallons.	Average Daily Yield. Gallons.	Rainfall. Inches.	Amount of Rainfall represented by flow in River.	
				Inches.	Percentage of total Rainfall.
January	2 716 000 000	87 612 900	3.566	1.998	56.03%
February	4 054 400 000	139 806 900	3.980	2.982	74.92 "
March	.....	.....	.....	.....	.....
April	.....	.....	.....	.....	.....
May	.....	.....	.....	.....	.....
June	.....	.....	.....	.....	.....
July	.....	.....	.....	.....	.....
August	.....	.....	.....	.....	.....
September	.....	.....	.....	.....	.....
October	.....	.....	.....	.....	.....
November	.....	.....	.....	.....	.....
December	.....	.....	.....	.....	.....
	.....	.....	.....	.....	.....

The rainfall since November, 1876, is an average of measurements at five places on the Sudbury water-shed.

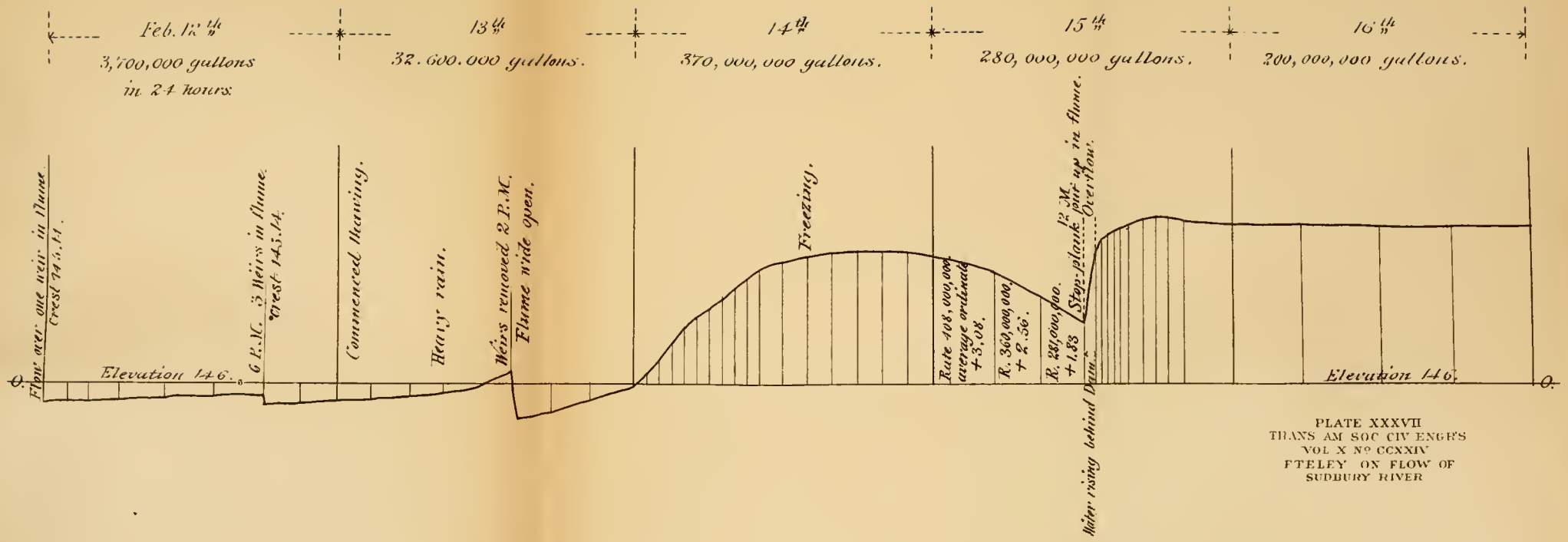


PLATE XXXVII
TRANS AM SOC CIV ENGR'S
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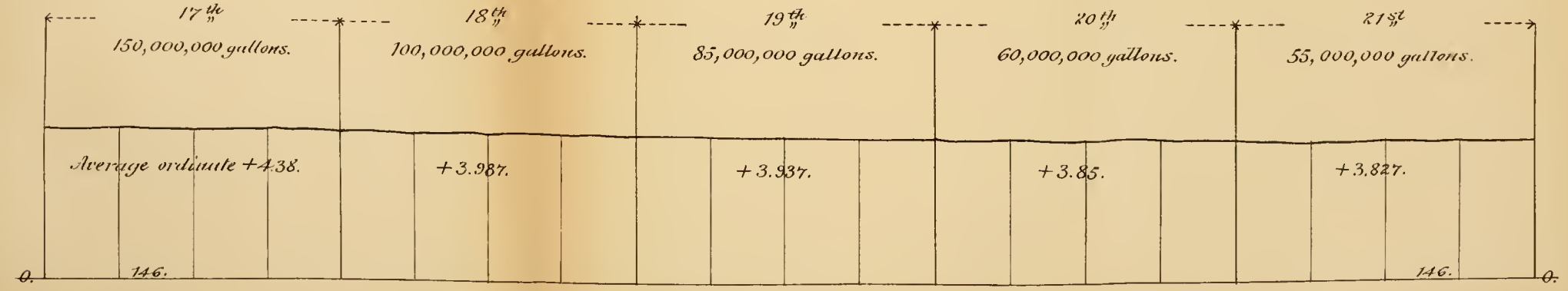
FTELEY ON FLOW OF
SUDBURY RIVER



SUDBURY RIVER WATER-SHED.

Years.	Flow for the Whole Year.						Flow for July, August, September and October.					
	Total yield of River. Gallons.	Av. daily yield. Gallons.	Av. yield in cub. ft. per second per sq. mile of drainage area.	Total Rainfall. Inches.	Rainfall Collected. Inches.	Rainfall Collected. Per-centage.	Total Flow. Gallons.	Av. daily yield. Gallons	Cub. ft. per second per sq. mile of drainage area.	Total Rainfall. Inches.	Rainfall Collected. Inches.	Rainfall Collected. Per-centage.
1875.....	27 593 700 000	75 599 200	1.50	45.490	20.418	44.88	3 770 000 000	30 650 400	0.60	17.38	2.790	16.05
1876.....	32 309 900 000	88 278 400	1.76	49.563	23.908	48.24	2 411 200 000	19 603 300	0.39	17.709	1.784	10.08
1877.....	34 444 750 000	94 369 200	1.88	44.018	25.487	57.90	2 439 350 000	19 832 100	0.39	15.471	1.805	11.67
1878.....	41 202 000 000	112 882 200	2.25	57.931	30.487	52.63	3 075 200 000	25 001 600	0.50	17.616	2.276	12.92
1879.....	25 528 900 000	69 942 200	1.38	41.419	18.775	45.33	1 841 800 000	14 974 000	0.30	13.129	1.355	10.32
1880.....	16 561 600 000	45 250 300	0.92	38.177	12.487	32.71	1 150 800 000	9 356 100	0.19	15.624	0.867	5.55
Averages...	29 606 810 000	81 040 500	1.615	46.100	21.927	47.56	2 448 060 000	19 902 900	0.40	16.155	1.813	11.22

Years.	Maximum Flow on any Day.		Minimum Flow in any Month.		Minimum Flow in any one Week	
	Flow for the day. Gallons	Yield in cub. feet per second per sq. mile of drainage area.	Average daily flow. Gallons.	Yield in cub. feet per second per sq. mile of drainage area.	Average daily flow. Gallons.	Yield in cub. feet per second per sq. mile of drainage area.
1875.....	970 100 000	19.30	abt. 8 000 000	0.16	.....	.....
1876.....	2 080 000 000	41.39	14 229 000	0.28	4 000 000	0.080
1877.....	1 109 800 000	22.08	4 633 300	0.09	1 800 000	0.036
1878.....	784 600 000	15.61	9 983 900	0.20	5 300 000	0.105
1879.....	1 080 000 000	21.36	5 500 000	0.11	.....	.....
1880.....	.....	.....	6 280 000	0.13	.....	.....
Averages...	1 204 900 000	23.95	8 104 400	0.16	3 700 000	0.074

Drainage area previous to 1879..... 77.75 sq. miles.
" " for " ..... 78.24 " "

Emma Hyde Oden.
146.
0.

Discussion on Rainfall and the Flow of Streams.

J. James R. Croes.—The Committee on the Gauging of Streams have been for some time urging upon members of the Society and other persons in positions which enable them to collect such data, the desirability of taking accurate and continuous measurements of the flow of streams of known water-shed, in connection with gaugings of the rain-fall. They take great pleasure in presenting the interesting paper from Mr. Fteley, giving the results of the most accurate and long-continued observations of this kind that have been made in this country.

These gaugings were instituted by order of Joseph P. Davis, M. Am. Soc. C. E., then City Engineer of Boston, in whose preliminary reports on an additional supply for that city, in 1873 and 1874, may be found a valuable compilation of facts and arguments with reference to the available quantity of water which may be depended upon from a known water-shed. It is only by continuous and long-continued observations that the actual capacity of supply of a stream can be obtained, and we hope that the publication of this record will incite other engineers to institute such observations and communicate the results to the Society for publication.

The past summer has been one of extreme drought throughout the North-eastern and Middle States, and there is little doubt that its effects will be felt during the coming year very seriously.

Where there is considerable storage accommodation, the ill effect of a dry season is not felt to its full extent during the drought, but some time after the rains have begun. While there is a deficiency of rain-fall, the stored water, both in the reservoirs and in the ground is drawn upon to supply the demand, and not only the first rains, but those which fall for some time after are absorbed in filling up the depleted storage. It is not uncommon also to lose a large proportion of the first rains by their rapid flowing off from either parched or frozen ground.

The extent of the present dry term may be judged to some extent from a short statement of facts collated from the newspapers of the past month.

In Kittery, York and Wells in Maine, wells and springs which have not failed for fifty years are now dry, and some farmers have to drive their stock two and three miles to water. At Nashua, New Hampshire, the mills are running on half time, owing to the scarcity of water. At Manchester,

New Hampshire, the source of supply, Lake Massabesic is lower than it has been for many years. The outlet is being deepened, and the city is supplied by water from the Merrimac river, pumped into the reservoir of one of the manufacturing companies. At Kingston, New York, wells and cisterns are dry, and water is carted from a distance, and sold in the streets by the tubfull. On the Delaware and Hudson Canal, navigation has been discontinued for some weeks, and most of the mills along the streams have entirely suspended work. Owing to the long drought it is said that less than one-half the usual amount of lumber will be rafted from the upper Delaware this fall.

At Mechanicsville, New Jersey, mills are stopped and many employees thrown out of work. At Reading, in Pennsylvania, the city has been deprived of water for ordinary household uses. The Chester, Pennsylvania, Water Works are unable to supply the town.

At Altoona, Pennsylvania, springs have dried up which were never known to fail before. At Paterson, New Jersey, the Passaic river is so low that it has been necessary to stop the mills for a day to get water to fill the reservoirs for city supply, On Staten Island, wells and cisterns have become dry, and water is in many instances compelled to be carted long distances. In Baltimore, the water in Lake Roland has been more than six feet below the dam, notwithstanding the pumping of from five to ten millions of gallons into it daily from the Gunpowder river. At Petersburgh, Virginia, the water in the reservoir has become so impure from drought that the Board of Health has forbidden its use for drinking purposes. At Richmond, Virginia, the water is so scarce that one reservoir was empty, and the other held so little that a portion of the city has been cut off from the supply, and great inconvenience caused. In New York City the storage reservoirs have been drawn very low, and unless copious rains soon fall, the effects of the drought will be very severely felt. The Brooklyn supply is so reduced that i has been necessary to make arrangements for pumping water from wells into the conduit.

Now, what we want is, to know at what intervals of time such seasons of water famine may be expected, and how their bad effects may be guarded against, and to what extent storage can be relied upon. The only way to find this out is by having such careful observations as Mr. Fteley has given us, and analyzing and comparing them.

The Chairman (Vice-President Welch).—In the absence of the author

of the paper, the Chairman of the Committee on the Gauging of Streams will give a summary of the principal facts stated in the paper, with regard to the ratio between the rain-fall and the flow of the stream.

J. J. R. Croes.—During the six years in which these continuous observations have been made on the Sudbury river, with a water-shed of 77.764 square miles, the rain-fall has varied from 38.177 inches to 57.931 inches, and the discharge of the stream from 12.487 to 30.487 inches per year on the water-shed. The percentage of rain-fall which reached the stream at the gauging point varied from 32.71 per cent. to 57.90 per cent., the flow for the five years being 47.56 per cent. of the total rain-fall.

F. Collingwood.—Do not the gaugings show that in the years of least rain-fall the percentage flowing off was least ?

J. J. R. Croes.—They do not altogether. The least percentage of the rainfall flowed off in 1880, when the rain-fall was the least, but in 1875 the percentage flowing off was less than in either 1877 or 1879, which were years of less rain-fall. The greatest percentage flowed off in 1877, when the rain-fall was 13.9 inches less than the greatest rainfall. No ratio can be traced between the amount of rain and the proportion of that rain which will reach the streams.

Joseph P. Davis.—The proportion which flows off will depend upon the manner in which the rain-fall is distributed throughout the year.

Ashbel Welch.—What ratio does the greatest flow bear to the extreme low water discharge ?

J. J. R. Croes.—It appears that the least discharge of the stream in any one week was at the rate of 1 800 000 gallons per day, or 0.036 cubic feet per second per square mile of drainage area, while the maximum discharge noted was 2 080 000 000 gallons per day or 41.39 cubic feet per second per square mile, being 1 150 times the least flow.

Ashbel Welch.—The amount of water which passes any point on any one day can not be considered a guide to the yield of the stream, particularly in cases where there are dams and mill ponds on the stream. The water may be held back by them, and cause an apparent discharge really much less than the actual flow of the stream.

Joseph P. Davis.—For that reason the minimum discharge of the Sudbury river is not taken at the rate of flow for any one day, but at the mean discharge for several days during the dryest time. The tables given by Mr. Fteley show the flow for a week in September, 1877, to have averaged only 0.036 cubic feet per second per square mile.

J. J. R. Croes.—That is a very small yield for a water-shed of that area. The notes which the committee published last year in their report (Proceedings A. S. C. E., Vol. V, p. 110) showed nothing as low as this except from an area of 20 square miles. We have received from Mr. W. R. Hutton (see p.) some notes of Maryland and Virginia rivers which show in the case of the Potomac river so extraordinarily small a flow, that that stream seems to be of an entirely different character from any Eastern rivers of which we have records. The flow at Cumberland where the drainage area is 1 364 square miles was stated, in 1837, by Mr. Patterson to be 25 cubic feet per second, or only 0.0183 cubic feet per second per square mile. This is not more than one-tenth of what we shall expect from the gaugings of rivers of the same water-shed in the Eastern States. The same stream at Great Falls, 17 miles from Washington, where the drainage area is 10 964 square miles, discharged in August, 1855, only 1 063 cubic feet per second, or 0.097 cubic feet per second per square mile, being about one-fifth of the discharge from nearly the same drainage area in the Connecticut river at its lowest recorded stage in August, 1876. J. H. Harlow, M. A. S. C. E., has furnished the results of a gauging of the Ohio river at Pittsburgh by himself in October, 1879. The discharge was then the least known for twenty-five years. The average of two measurements was 2 271 cubic feet per second, assuming the area drained to be as stated by Mr. W. Milnor Roberts in his report (Ex. Doc., 72, H. of R., 41st Congress, 3d Session, page 160) 19 900 square miles, this discharge was at the rate of 0.114 cubic feet per second per square mile. This shows a marked similarity between the low water discharge of the Ohio and the Potomac, the headwaters of both of which streams are about of the same meridian.

Clemens Herschel.—The flow of the Connecticut river near Dartmouth, New Hampshire, was gauged on October 9, 1880, by means of floating tubes in a selected channel. The result which was probably correct within five per cent., was 1 006 cubic feet per second. The drainage area was about 3 287 square miles, and the discharge was therefore 0.306 cubic feet per second per square mile.

J. J. R. Croes.—As to maximum flow, the Sudbury river shows a very small quantity, when compared with several other streams of the same water-shed. The greatest flow noted by Mr. Fteley was in March, 1876, when the drainage was 42.17 cubic feet per second per square mile. Against this we have the flood of 1843, in Flat river, R. I.,

mentioned by Mr. Shedd, of 120.75 cubic feet per second per square mile from an area of 61 square miles, and the Rock creek flood given by Mr. Hutton as 126.4 cubic feet per second per square mile from an area of 77.5 square miles. In this connection, the attention of members interested in this subject may be called to the interesting discussion on the flood discharges of stream by the Engineers' Club of Philadelphia, and published in their proceedings (Vol. I., pages 146 and 194).

Joseph P. Davis.—In the construction of the dams for the storage reservoirs on the Sudbury river, the overflow weirs were proportioned to carry off, without injury, floods of 160 cubic feet per second per square mile. Although the gaugings had not shown a discharge of more than one-fourth of that amount, the examinations of Mr. James B. Francis proved that such a flood was probable at some time.

Marshall M. Tidd.—The discharge of water from Horn Pond in Massachusetts, one of the tributaries of the Mystic supply of the City of Boston, was measured at intervals during the years 1874 and 1875. The table on the next page and plate XXXVIII show the fluctuations of the discharge and approximately the aggregate discharge. The rate of flow is given in cubic feet per second per square mile of the drainage area of the pond, which is 7.60 square miles; the monthly discharge is in inches in depth on the water-shed.

The discharge for the year ending September 1, 1875 was equivalent to 26.362 inches on the water-shed, or at the rate of 14.76 cubic feet per second. The maximum flow was on February 25, 1875, and was at the rate of 49.82 cubic feet per second, or 6.55 cubic feet per second per square mile. The minimum flow was on November 21, 1874, and was at the rate of 2.21 cubic feet per second, or about 0.30 cubic feet per second per square mile.

Flow of Horn Pond.

Date of Observation.	Discharge per cu. ft. per second per sq. mile.	Discharge per month in inches on Water-shed.	Rain-fall.	Date of Observation.	Discharge per cu. ft. per second per sq. mile.	Discharge per month in inches on Water-shed.	Rain-fall.
1874.				1875.			
Aug. 8.....	1.577	.....	6.68	April 3.....	4.168		
Sept. 8.....	0.694			" 5.....	5.851		
" 14.....	1.151			" 15.....	2.807	4.012	2.87
" 16.....	1.134	0.990	1.87	" 29.....	2.667		
" 24.....	0.756			May 4.....	2.808		
" 29.....	0.694			" 7.....	3.439		
Oct. 2.....	0.921			" 19.....	3.206		
" 7.....	0.694			" 17.....	3.101	3.368	3.93
" 12.....	0.921	0.744	1.06	" 21.....	2.808		
" 17.....	0.694			" 29.....	2.667		
" 21.....	0.417			June 9.....	2.808		
" 30.....	0.450			" 12.....	3.748		
Nov. 4.....	0.328			" 19.....	2.808	3.308	.....
" 9.....	0.328			" 22.....	2.667		
" 17.....	0.567	0.505	2.5	July 8.....	2.667		
" 21.....	0.291			" 15.....	2.230	2.570	.....
" 24.....	0.533			" 24.....	1.854		
Dec. 8.....	0.921	0.874	1.62	Aug. 4.....	2.031		
1875.				" 9.....	2.230		
Jan. 14.....	0.417	0.553	3.06	" 14.....	1.854	2.859	.....
" 18.....	0.450			" 24.....	3.967		
Feb. 2.....	0.533			Sept. 4.....	2.230		
" 5.....	1.854			" 24.....	2.230	2.345	.....
" 13.....	2.289	2.982	3.0	Oct. 5.....	1.854		
" 20.....	1.854			" 11.....	2.808	3.010	.....
" 25.....	6.5564			Nov. 1.....	3.101	3.493	.....
Mar. 1.....	3.439			Dec. 24.....	3.101	3.486	.....
" 9.....	3.100	3.597	6.0	1876.			
" 17.....	2.667			Jan. 22.....	2.808		

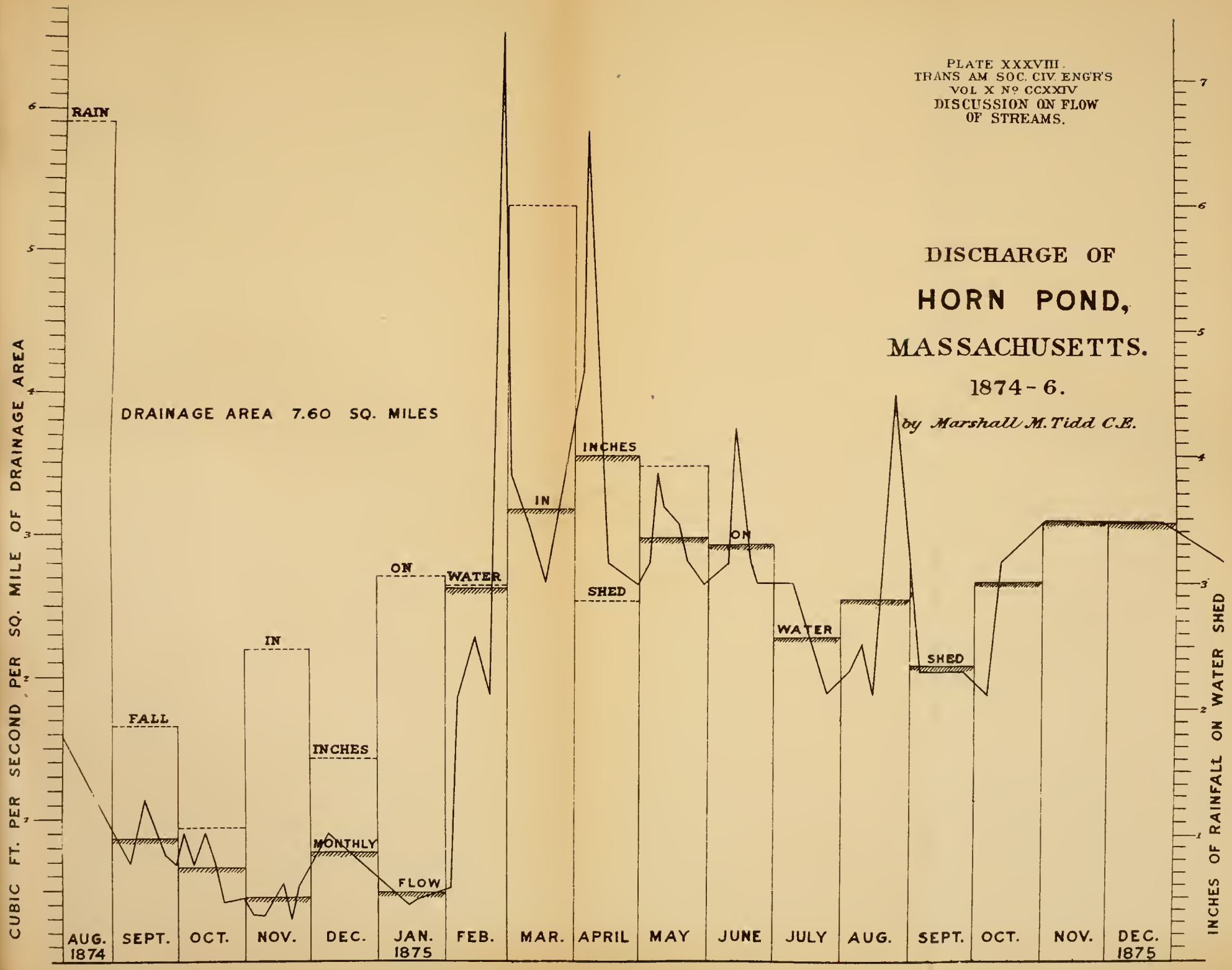


PLATE XXXVIII.
TRANS AM SOC. CIV. ENG'RS
VOL X Nº CCXXIV
DISCUSSION ON FLOW
OF STREAMS.
DISCHARGE OF
HORN POND,
MASSACHUSETTS.
1874-6.
by Marshall M. Tidd C.E.
DRAINAGE AREA 7.60 SQ. MILES
RAIN
FALL
IN
INCHES
ON
WATER
SHED
MONTHLY
FLOW
CUBIC FT. PER SECOND PER SQ. MILE OF DRAINAGE AREA
INCHES OF RAINFALL ON WATER SHED
AUG. 1874
SEPT.
OCT.
NOV.
DEC.
JAN. 1875
FEB.
MAR.
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC. 1875

F. Collingwood.—With reference to the proportion of the rain-fall which flows off through the streams, I think it will be found that it is least during the season when plowing is going on. The ground then absorbs more water, owing to the breaking up of the surface.

The percentage depends largely also on the distribution of the rain-fall. More water will reach the streams when there is a succession of light rains, keeping the ground full, than when the same amount of rain is precipitated in a few storms.

J. J. R. Croes.—In this latitude, the least percentage of the monthly rain-fall which reaches the streams is during the months of July and August. From October to April the ratio of rain to flow cannot be depended upon for any deductions, in consequence of a part of the precipitation being in the form of snow, which lies for some time. Between December and April the flow of the streams is likely, in two months, at least, to be from 100 to 150 per cent. of the precipitation. The flow of May and June is more apt to represent the normal discharge.

William R. Hutton.—The data from which the table on the following page has been prepared have been gathered from official reports of officers of the United States Coast Survey and army.

The flow discharges of the Potomac are not more than approximations.

Ashbel Welch.—The river Delaware, at the driest seasons, discharges a little less than 2 000 cubic feet per second. In the great floods about 350 000 cubic feet per second, nearly 200 times more than the minimum. The drainage area above my point of observation is somewhere between 6 500 and 7 000 square miles. In regard to Mr. Collingwood's suggestion, my observation is that when gentle rains come through the dry seasons they do not affect the streams at the time at all; for instance, in the months of September and October of this year we had, during that time, 3½ inches of rain, but the brooks were not affected perceptibly; it all went into the ground or evaporated. On the other hand, in some districts that I am acquainted with a hard rain passes off within a few hours. I know of one small district near the place where I live, where the soil is red shale, almost impervious to water; the hills are covered with very little vegetation, and when a hard rain comes the whole amount passes off in six or eight hours, and a little stream draining a few square miles will discharge, for a short time, 5 000 or 6 000 cubic feet per second.

DISCHARGE OF STREAMS—RATIO OF HIGH AND LOW WATER DISCHARGES TO AREA DRAINED.

CONTRIBUTED BY WILLIAM R. HUTTON.

		Extreme Length of Area Drained —Miles.	Area Drained—Square Miles.	Discharge in Cub. feet per Second.	Cubic feet per Second per Sq. Mile.	Date.	Authority.	Remarks.
1	Potomac River at Cumberland, Md	65	1 364	25	0.0183	1873	Patterson	Lowest water. Ordinary low water of dry years is more than twice as much.
2	" "	65	1 364	11 456	84.			High flood.
3	" "	65	1 364	17 900	131.	Nov., 1877.		Extremely high water. Great flood.
4	" Dam No. 5	153	4 640	363	0.0783			Very low water—approximate.
5	" "	153	4 640	72 000	15.65	Feb., 1870.		High flood.
6	" "	153	4 640	92 772	20.00			Extraordinary flood.
7	" Great Falls, Md	244	10 964	1 063	0.097	Aug., 1855.	Hutton	Lowest. Ordinary low water of dry seasons 50% more.
8	" Georgetown, D. C	260	11 124	175 000	15.73	Spring, 1852		Extraordinary flood 1852; those of 1870 and 1877 were considerably higher, but no data for computations. This is approximate.
9	Rock Creek at Hoyle's Mill, D. C	18	64.4	29.3	0.458	Oct., 1852.	Meigs	Ordinary summer water.
10	" " "	18	64.4	7.5	0.114			Very low water—rare.
11	" Georgetown, D. C	26	77.5	9 790	126.4			High flood.
12	Kanawha River on Charleston pool, Va	270	8 900	1 100	0.123	1838	Gill	Extreme low water.
13	" " "	270	8 900	94 460	10.61	July 13, 1875	Scott	Flood of 26.5 feet.
14	" " "	270	8 900	118 291	13.29	Aug. 3, 1875	Scott	Flood of 32.8 feet.
15	Greenbrier River, mouth of Howard's Creek, Va	69	810	97	0.120	Sep. 5, 1826	McNeil	Very low water.

George W. Dresser.—I would like to ask Mr. Welch if he thinks that in the case of the gentle rains that he refers to, where the water is apparently all soaked into the ground, the effect of the water is felt afterwards in the stream.

Ashbel Welch.—Yes, sir; it disappears entirely, but it ultimately reaches water-bearing strata, and then it comes out, and if it goes into the ground it remains for a time, but it will appear in the stream sooner or later. In the case of the hard rains, it does not have time to get down; it simply runs off.

I remember on one occasion a rain in which about 12 inches fell in about as many hours in one night. It was not determined by a rain gauge, because the rain gauges ran over, but by different tubs, and pails, and troughs apart from buildings. I was satisfied that during these 12 or 14 hours about a foot fell, but it was over a very narrow district. On either side of it was a very hard rain, but none like that, and in that district it caused a very great deal of damage, and one part of the damage was a break in the canal of which I had charge, near Boundbrook.

Samuel L. Smedley.—What year was that?

The Chair.—It was in August, 1843. The most destructive rain storms I have seen have been in August, and next to that, July.

Samuel L. Smedley.—Has there been any change in the amount of rain-fall since the cutting off of the forests?

Ashbel Welch.—When I first knew the Delaware, nearly half a century ago, the minimum flow was probably 4 000 cubic feet per second—twice as much as it is now. The discharge in the highest flood ever known before 1841, that of 1787, was not more than two-thirds as much as that in the great flood of 1841.

J. J. R. Croes.—Has there been any great flood since 1841?

Ashbel Welch.—There have been two, one of which was nearly, if not quite as high. The flood of 1841 and two subsequent floods must have discharged nearly twice as much water as any previous floods since 1787, and 50 per cent. more than the flood of 1787. I suppose that there is not, at the lowest stages, more than half the water in the Delaware that there was half a century ago, and that the highest floods carry off 50 per cent. more per hour than any flood known before 1841.

J. J. R. Croes.—Are these figures the result of measurement?

Ashbel Welch.—The 2 000 cubic feet is measurement some years ago. The 4 000 cubic feet is a very rough measurement at the time in

various ways, none of them accurate, but still corroborating each other, so that I probably get the result within 10 per cent. of the truth.

Samuel L. Smedley.—In regard to the Delaware, I would like to know whether you have any record of rain-fall over an extended period?

Ashbel Welch.—No, sir. Very few rain gauges were kept at that time. I had a conversation with Professor Henry several years ago on the subject of cutting off the woods in relation to the rain-fall. He had paid some attention to that subject, and he said, so far as he could see, the cutting off of the woods did not diminish the rainfall; that there was just as much fell afterwards as before. He said, in regard to places that came under his notice, that the difference is this: while the country was covered with woods and swamps, and while these swamps were covered with leaves and vegetable matter, the rain that fell stopped there, and ran off gradually; but after the country was cleared it ran off immediately, but the actual rain-fall was as great in one case as the other. It would be interesting to test this question still further.

Julius E. Hilgard.—In regard to data on which this opinion of Professor Henry's was based, I may say that they were observations which have been kept at Marietta, Ohio, for 50 years, and show that during the decennial periods the rainfall at that place was identically the same. The effects of cutting off the woods have been very clearly felt. The wells have given out, the springs dried up in the summer; brooks that always had a flow of water in them are entirely dry in the summer, and agriculture has been very much affected. Still, the rain-fall has actually been the same. I only wish to mention the precise data.

Ashbel Welch.—There is one consolation about this matter: while the cutting off of the woods and the clearing up of the land causes the water to run off a good deal faster, yet, as the land is further cultivated and converted from pasture with shallow soil to meadow or ploughed land with deep soil, the soil is made more retentive by increasing the thickness of the sponge on its surface, and it gives off the water more gradually, so that as the country is cultivated this inconvenience of exceedingly low streams and wells is somewhat ameliorated.

Thomas C. Clarke.—That is not the case all through the West. In a prairie country, where there is hardly any timber, it is well known that the prairie grass and sod acts like a sponge, whereas when cultivation takes place the drainage leads the water off rapidly.

Ashbel Welch.—In this part of the country, in most cases, after the

land is cleared, it is left hard and almost naked, with no depth of vegetable mould. From this the water runs off immediately. Plough that land and make it porous, and fill it with roots, and cover it with vegetable mould of some depth, and it will absorb a great deal of water and give it off gradually. I can see that cultivation may operate the other way on the prairies. When you destroy the prairie grass, and substitute a less rank vegetation, the depth, and porosity, and retentiveness of the mould may be diminished. So Mr. Clarke's view and mine do not conflict. If you watch a hillside in the rain, where the ground is uncultivated and hard, you will see the water running down in numerous little rills; but if the ground is cultivated and the mould deep, the same rain, if not very hard, will all go into the ground.

Octave Chanute.—Mr. Welch stated, as well as Mr. Hilgard, that Prof. Henry's opinion was that the annual rain-fall was not diminished by the diminishing of the forests. I would ask the Chairman whether he has any other facts that bear upon that subject, and which seem to confirm that opinion of Mr. Henry? If I remember correctly, in Mr. Marsh's book, entitled "Man and Nature," he takes the ground that the experience, more particularly of the old world, is that the rain fall does annually diminish in consequence of the cutting away of the trees, and instances the land about the Pyrenees between France and Spain, and the whole of Great Britain and Germany. The question is of great importance for us in this country, because as we proceed westward we know the rainfall diminishes; that while it is some 45 inches a year on the Atlantic seaboard, when the Missouri river is reached, the rain-fall diminishes to about 32 inches, and that at the 100th meridian, upon the edge of the arable portion of the United States, the rainfall does not exceed 28 inches, while on the plains about 500 miles west of the Missouri river, it drops down to 6 or 9 inches. The problem presented in that region is to compel a greater rain-fall. The soil is abundantly rich, but nothing can be grown without more moisture. As I say, it is of the greatest importance for us to know whether the cutting away of forests does diminish rainfall, and if by planting trees we can increase it.

Charles E. Emery.—There are some facts in regard to the great Sahara desert. It will be remembered that there are driven wells upon it, and that artificial oases are formed at those places, and that when water is thus brought to the surface, vegetation extends till sometimes rain-falls will take place in the neighborhood. That was the effect of

building the Suez Canal. I don't recollect the details, but in that direction there will be found some very valuable information on this subject.

J. E. Hilgard.—Marietta, the place mentioned, is the farthest place West where observations have been taken for a sufficient length of time to arrive at the facts. I am only speaking of observed facts. On the Atlantic slope of the Alleghanies there are many stations where meteorological observations extend for a longer period than that; for instance, in Providence, Rhode Island, by Prof. Caswell, which show the same fact. Those at Marietta were made by Mr. Andrews, the father of the present Professor Andrews, there. While they show that the average amount of rain has been the same, it may be questioned whether there might not be a change in its distribution; whether, for instance, there are now heavier rains at longer intervals. Classing them by weeks, throughout the year, has shown that there has been no material difference in the period covered by that series of observations. Those are all the facts that I know of.

In regard to the diminution of water in wells and streams in Europe, especially in Germany, in the region of East Prussia and the Baltic, a very late work has been published. We know in those countries there are much more numerous data to be obtained than here. I have only had time to look at it in a general way. The general facts are the same as here. The amount of rain-fall has not diminished, but its conservation has been affected by the clearing of the country. Some points that seem contradictory may be readily explained, while others, to me, are not susceptible of a physical explanation; for instance, that the cutting of the woods of so small an altitude on the great elevation of the Pyrenees should change the particular mode in which the vapor is condensed in passing those mountains.

Although the cutting off of the forests might produce a sensible effect on the condensation of vapor, yet, so far as the general distribution of rain-fall in the United States Territory is concerned, it is very obvious that the only effective mode of curing the rainless districts would be to remove the mountains. The supply of vapor comes from the Pacific Ocean, and as the atmosphere's circulation is from west to east, it is carried eastward and precipitated when it comes in contact with the Rocky Mountains, and that is what makes the Eastern slope dry in the summer. In winter, when the moisture-bearing air is colder, there is less precipitation on the Western slopes, and we have snows on the Eastern slope

where we have no rains in summer. The difference between the Eastern and the Western side of the Mississippi Valley is due to its rain fall being mainly derived from the vapor from the Gulf of Mexico, moving north-eastward with the prevailing southwest winds of summer, parallel with the Alleghany chain of mountains. Hence the amount of rainfall on the Western and Eastern slopes of the Alleghanies is sensibly the same.

Ashbel Welch.—I ought to say that Professor Henry made the remark which I quoted when we were talking about the country east of the Alleghanies, and no doubt he had that country in his mind. He did not state the proposition as a universal one, and therefore it might be quite consistent with it that in the desert of Sahara, or in Egypt, the rain-fall might be increased by planting trees.

O. Chanute.—My idea was not to question the fact with respect to observations in this country, but to inquire, rather, whether they were substantiated elsewhere. It is clear that a few observations taken in the Atlantic slope for a period of 40 or 50 years are not to be relied upon exclusively to draw therefrom general conclusions. As to the effect of cutting off the trees, it is my opinion that those people who have held that the clearing of the forests diminishes the rain-fall, attribute the effect of the trees upon the rainfall, not so much to their height above the surface of the ground as to some chemical effect produced upon the atmosphere, perhaps that of the carbonic acid gas, which the leaves of the trees absorb, and which may increase the amount of condensation and precipitation of the clouds.

With respect to the other theory, which has been stated by Mr. Hilgard, I would call attention to the fact that the rainfall does not diminish over the plains from the west easterly, but from the east towards the west, and it diminishes with great rapidity over a particular belt of country. At 100 miles west of the Missouri river it is about 28 inches, but 400 miles west of this it is diminished to 9 inches, and in some localities it is only 6 inches. The clouds which bring the rains that fall over the plains come from the east and south, and not a drop, I think, passes west of the Rocky Mountains, the clouds having poured out part of their contents over the Middle and Western States as far as the 100th meridian, scud over the space west of this without dropping any rain, and are finally wrung dry by the cold summits of the Rocky Mountains.

J. J. R. Croes.—The observations to which Mr. Hilgard alludes are probably those of Sir Gustav Wex, in his treatises on the decrease of

water in springs, creeks and rivers, contemporaneously with an increase in height of floods in cultivated countries. The first treatise was published in 1873, the second in 1879. The latter has been translated by Gen. G. Weitzel, U. S. A., and issued from the the Government printing office.

From observations at 51 stations on 13 rivers, during periods ranging from 20 to 150 years, he reaches the conclusion, that not only the mean flow, but also the maximum and minimum discharges are annually decreasing. This, at least, would appear from his statements, notwithstanding the title of his book. He considers also that this decrease of flow is due to a decrease of rain-fall. In support of this opinion he quotes only two instances, one at Bodenbach, in the Erz Mountains of Bohemia, where two periods of twenty-two years each are compared, showing a decrease in the annual mean of 1.26 inches; the other at Geneva, for two periods of 35 and 11 years, showing a decrease of 3.3 inches.

Wex's conclusions have been disputed by several German scientists. As regards the amount of discharge we have not, in America, observations made with accuracy extending over a sufficient time to determine whether it is increasing or diminishing.

As for the rain-fall, it is certainly not diminishing on the seaboard in this latitude.

Mr. Daniel Draper, the Director of the Central Park Meteorological Observatory, discussed this subject at some length in his reports for 1873 and 1876. The conclusion reached by him was, that although there are large variations from year to year, no perceptible change occurs when long periods are compared.

In fact, so far from the rain-fall diminishing it appears to be at present increasing here.

The mean rain-fall at Philadelphia from 1827 to 1844, 18 years, was 43.31 inches; from 1845 to 1861, 17 years, was 45.18 inches, and from 1862 to 1879, 18 years, was 48.31 inches.

In New York City the mean precipitation from 1836 to 1848, 13 years, was 40.47 inches; from 1849 to 1862, 14 years, was 48.39 inches, and from 1862 to 1876, 14 years, was 49.53 inches.

At Providence, R. I., taking 15 year periods, the mean rain-fall was, from 1832 to 1846, 39.50 inches; from 1847 to 1861, 43.97, and from 1862 to 1876, 48.02 inches.

At Boston, from 1850 to 1865, 14 years, it was 51.09 inches, and from

1866 to 1879, 14 years, it was 49.51 inches. In this case there was a small decrease. In all the others a decided increase.

The danger of drawing conclusions as to the average discharge of streams, from partial observations or too short periods of time, is well illustrated from the records of the flow of Lake Cochituate, one of the Boston sources of supply. From 1858 to 1868, 11 years, the mean flow was 20.18 inches, and from 1869 to 1879, again 11 years, it was 21.13 inches, a decided increase. But if we begin with 1857, a year of large flow, and end with 1880, a year of very small flow, the mean for the first 12 years is 22.38 inches, and for the second twelve years is 20.25 inches, showing an equally decided decrease of flow in the later period.

William R. Hutton.—The following note by the late M. Belgrand, in charge of the water supply of Paris, may be of interest in connection with this subject. He remarks that the seasons from 1857 to 1865 were of extraordinary dryness in France, as shown by the following table, which gives the number of days that the river Seine was below the zero of the gauge of La Tournelle, the reference for Paris, which is supposed to be the lowest water known in 1719.

From 1732 to 1799,	67 years,	average..	0.57	days	per	annum.
1800 " 1826,	26 "	"	.. 10.67	"	"	
1826 " 1856,	30 "	"	.. 2.23	"	"	
1856 " 1865,	9 "	"	..100.00	"	"	

Alfred G. Compton.—It seems to me that the observation of the rain-fall at a small number of stations within a water-shed does not furnish sufficient data to estimate the yield from the whole area. There are so many local storms of small area that measurements of rain-fall at a single point do not give the average of a large district, like the drainage area of the Delaware river for instance. The measurement of the flow of a stream gives us correct data independent of the rain-fall.

Joseph P. Davis.—Gaugings of a stream, if they extend over a sufficient length of time to include seasons of great drought, are undoubtedly the most reliable, but usually the engineer is called upon to make estimates of the yield of water-sheds where no gaugings of the streams have been made, so that, practically, he has to rely upon the record of rain-fall, and it is found that a single rain gauge, kept for a number of years, within the area, or in its vicinity, gives a very good average, in most cases, of the rain on the water-shed.

J. J. R. Cross.—The Department of Public Works of New York City assumes the rain-fall at the Boyd's Corners Saratoga Reservoir as the basis of computation. This is in the Croton Valley, 23 miles north of the Croton Dam, and 16 miles from the Hudson river, 550 feet above tide level. There were no other rain gauges kept in the Croton Basin until 1879, when one was established at the Middle Branch Reservoir, 8 miles southeast of Boyd's Corners.

Between that point and New York City some rain gauges have been kept, the record of which is appended. Peekskill, Sing Sing and Tarrytown are on the Hudson river. The other points are inland. Boyd's Corners and the Middle Branch Reservoir are the only points in the Croton Basin. The ordinates of each point are given in miles, referred to the New York City Hall and a meridian passing through it.

	Boyd's Corners. 51 N. 14 E.	Middle Branch. 44 N. 20 E.	Sing Sing. 30 N. 8 E.	Peekskill. 40 N. 3 E.	Tarrytown. 24 N. 8 E.	White Plains. 21 N. 12 E.	New York City.
1863	.....	.....	.....	.....	42.35	.....	57.03
1864	.....	.....	.....	.....	38.73	.....	47.61
1865	.....	.....	.....	.....	49.73	.....	62.98
1866	.....	.....	75.70	.....	47.30	.....	52.23
1867	50.07	.....	88.02	.....	45.73	.....	54.66
1868	50.33	.....	93.42	.....	53.48	.....	64.03
1869	48.36	.....	82.98	.....	50.80	.....	45.47
1870	44.63	.....	.....	.....	47.51	.....	39.25
1871	48.94	.....	.....	.....	60.39	.....	51.26
1872	40.74	.....	.....	.....	42.75	.....	42.49
1873	43.87	.....	.....	.....	50.44	41.60	47.99
1874	42.37	.....	.....	42.00	49.38	60.30	45.83
1875	43.66	.....	.....	45.73	59.38	63.80	40.90
1876	40.68	.....	.....	41.46	47.78	63.50	41.77
1877	46.03	.....	.....	43.52	45.58	61.95	40.18
1878	54.14	.....	.....	41.92	47.86	64.50	48.66
1879	46.08	44.27	.....	40.10	42.28	63.60	.....
1880	38.52	35.45	.....	35.96	36.46	59.43	.....

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CCXXV.

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COMPARATIVE ECONOMY OF STEEL RAILS WITH LIGHT AND HEAVY HEADS.

By ASHBEL WELCH, Vice-President A. S. C. E.

READ AT THE 13TH ANNUAL CONVENTION, JUNE 15TH, 1881.

I shall consider the rail as consisting of two parts—the consumable part, all of which may be safely worn away; and the residuary part, which must not be worn at all, and which must be strong enough, after the consumable part is worn off, to carry the machinery safely. Of course, the consumable part—the *wearer*—is all in the upper part of the head. The residuary part—the *bearer*, consisting of the lower part of the head and of the stem and base—must be strong enough, after the consumable part is worn off, to carry the load safely.

The amount of strength required depends on the weight, inelasticity and speed of the machinery, the load upon a wheel, the distance apart and quality of the ties, and the condition of the road-bed. With iron rails, it is necessary to allow for the depreciation of the residuary part

of the head, and even of the stem and base, by the repeated concussions on the head ; but with steel, owing to its elasticity and homogeneousness, and the absence of welds, no material deterioration of the residuary part takes place. A steel rail wears out ; an iron rail is knocked to pieces before it is worn out.

Of course, when the rail is made heavier, the machinery and loads being constant, the different parts of the rail should not be increased proportionably, for that would give unnecessary weight to the residuary part, which we suppose to have been found strong enough already ; but the additional weight should be put on the head, so as to be available for wear.

Commonly, on the same system of roads the same machinery is used and the same loads carried on the branches as on the main lines, and, therefore, the residuary rail must be strong in one case as in the other.

In planning a steel rail, the first thing to be done is to fix upon a residuary rail strong enough to carry safely the machinery and the load that are to run over it. Of course, the weights, speeds, springs, ties and road-bed, and possible increase of weights and speeds, must be taken into consideration. So many unknown quantities affect the question of strength required, that it cannot be found by calculation alone, but by experience, under the same or similar circumstances. The base should be broad enough not to crush or wear out the tie, and its area a little greater than that of the residuary part of the head. The stem should be as thin as experience has shown to be perfectly safe (for its thickness adds little to the strength of the rail) ; no existing circumstances require more than half an inch ; but the usual height could be increased with advantage, for that would give opportunity to increase the strength of the splices.

The size of the consumable part of the rail will then be governed by the amount of traffic expected, taking also into consideration the greater wear per million of tons produced by greater weights on a wheel, higher speeds, poorer springs, steeper grades and sharper curves. The wear on a steep grade and sharp curve is sometimes as much as five times the wear of the same traffic on level tangents. Speaking generally, the consumable part of the rail should be proportioned to the amount of traffic, the residuary part to the weight on a wheel.

A small percentage of metal added to the head of most of the steel

rails in use adds a comparatively large percentage to their durability. In most cases, only about fifteen per cent. of the weight of the rail can be worn off from the head, all the rest—eighty-five per cent. of the whole original weight—being required to carry the load safely. By adding fifteen per cent. to the weight of such rails, putting it in the right place, their duration is doubled. On the other hand, interest must be paid on the cost of the additional metal before it comes into use at all during the whole time in which the original unincreased consumable quantity is wearing off. With heavy traffic, endurance; with light traffic, interest, is the weighty consideration.

I propose to give a very simple rule to find, between these conflicting considerations, the point of greatest economy, and to illustrate by the lightest steel rails used on main lines in the past, and by the heavier steel rails which are coming into use for the future.

The principles, and some of the formulæ, used in the following investigation were published, after careful consideration, in the journal of the Franklin Institute about ten years ago. I shall repeat so much of what was then written as may be necessary to make my calculations clear.

Much of the difficulty of such an investigation as this comes from the ambiguity of the term value. The intrinsic value of rails is measured by their capacity for usefulness; the exchangeable value is determined by that and the relative supply and demand, and the economic value, as I have called it, is measured by their combined capacity and opportunity for usefulness, under the actual circumstances where they are used. A heavy steel rail, laid in a car shed, has many times the intrinsic value of a light iron rail, but it has no more economic value, for, though it has the capacity, it has not the opportunity to do more than the iron rail in that situation can do just as well. A splendid hotel, in an inaccessible wilderness, might have ever so much intrinsic value or capacity for usefulness, but having no opportunity for usefulness, it would have no economic value; and there being all supply, and no demand, it would have no exchangeable value.

An engineer is likely to think of intrinsic value, a merchant of exchangeable, a shareholder of economic value.

Those who have ruined their employers by splendid engineering have commonly created capacity far in excess of opportunity for usefulness.

I shall use the term value only in its economic sense, that is, measured by combined capacity and opportunity for usefulness where the thing is actually used. This distinction is vital, and must be borne in mind.

I have, in all cases, reduced future usefulness and future expenses chargeable against it to present equivalents. All the values used are, therefore, present values.

In the present calculations, it is assumed that the traffic and the weight of machinery will continue uniform. It is easy, however, to apply the same processes and formulæ to cases where the traffic increases or diminishes.

It will be most convenient to consider the rails not by pounds per yard, but by tons to the mile, and the cost not per ton, but per mile.

The unit of cost and of value I shall use is that of a mile of rails laid down ready for use.

To facilitate the comparison of the values of rails of different durations with each other, I shall compare them both with the value of rails that, under the same circumstances, would last forever. The relations of the destructibles to the indestructible are simpler than that of the destructibles to each other.

We must assume, as a basis, that rails of some certain duration have, in the circumstances where used, a certain economic present value. The problem is to find the present economic value of those that in the same circumstances have some other duration. In the solution, we must take into consideration the rate of interest on cost and the loss in each case on renewal.

Let C be the cost of the rails in a mile of track, including hauling, handling, laying, and all other expenses, so as to be ready for use, which rails will last the time T, and which cost, in the present calculations, we shall suppose to be their true economic value; a, the rate of accumulated interest compounded every six months for that time; L, the loss on renewal with the same kind of rail, including all expenses, inconveniences, detentions and risks; and V the economic value of a mile of rails in the same circumstances that would last forever, inferred from the value of those that will last the time T. Also, let C' be the cost, and R the true economic present value for perpetuation of the rails that will last some other time, T', and L', the loss on their renewal, and a', the rate of accumulated interest for the time T'.

To make the rails that would last forever just as desirable at their valuation as the rails that will last the time T at their cost, the current charges against each, up to the end of that time, must be the same. The only charge against the indestructible is the accumulated interest on its valuation up to the end of that time, represented by aV. If the owner has borrowed the money, he has probably paid this interest annually, or semi-annually; but it amounts to the same thing as if he paid the compounded accumulated interest at the end of the period. Then the rails are just as they were at first, and the owner starts anew on the next period just as he did on the first. The current charge against the destructible rails for the same period consists of two parts, the accumulated interest on the cost, represented by aC, and the loss on renewal, L. After the renewal, the rails are just as they were at first, the owner has paid $a\ C + L$, and then enters on the next period just as he did on the first. The current charge against both being the same, we get the all-important equation, $aV = aC + L$. Dividing both sides of the equation by a, we get $V = C + \frac{L}{a}$.

Let R be the real economic value of the rails that will last some other time T', then, in the same manner as above, the current charge against them, up to end of that time, will be $a'R$ for interest and L' for the loss on renewal, the whole being $a'R + L'$, and then all is as it was at first. But the current charge for the same period against the indestructible rails is $a'V$; so that $a'V = a'R + L'$ and $V = R + \frac{L'}{a'}$ and $R = V - \frac{L'}{a'}$

As $V = C + \frac{L}{a}$, and also to $R + \frac{L'}{a'}$ $\therefore$ $R = C + \frac{L}{a} - \frac{L'}{a'}$.

V having unlimited capacity has unlimited intrinsic value; but its economic value is limited by its opportunities for usefulness, and that is in this case measured by the interest and expense with which destructible rails are chargeable, and which would be saved by the indestructible rails. Hence V is greater with a large than with a small tonnage, and greater where the loss on renewal is heavy than where it is light, for in the one case its opportunities of usefulness, or what amounts to the same thing, its savings of expense, are greater than in the other.

The economic value of R is increased by the durability of the rails, diminished by the greater interest charged against them. If the traffic

is heavy, the gain from their endurance is great; if the traffic is light, that gain may be more than overcome by heavy interest.

The foregoing formulæ, and the following tables and profiles, apply only to cases where the rails are for perpetuation, and not where the rails, when worn out, are to be replaced with some other kind. It is easy, however, to make a rule to find the value for replacement.

V and R are *present* values, and C and C' present costs, $\frac{L}{1+a}$ is the present value of the first renewal, and supposing traffic, interest and prices constant, $\frac{L}{a}$ is the present value of that renewal, and of all its successors forever.

If an absolutely indestructible rail could be got, the investment V would be greater than with R or C, and always continue so; but the absence of all cost of renewals would be equivalent to interest on the excess of investment.

Before we apply our principles, we must estimate as well as we can the facts we are to deal with, the amount of traffic, and its probable variations, the weight, speed, etc., of the machinery, the amount of metal worn off in that case per million tons of gross load, or the amount per annum, the cost of a mile of new track now, with rails of given weights, the loss on the renewals depending partly on what must be paid at the time for new rails and what can be got for the old, and whether all these things are constant or varying.

It may be asked, if we must depend on experience and judgment for all this data, why not for the settlement of the whole question? True, no rules of calculation can furnish data or supersede judgment in its proper sphere. True, there are many things such calculations cannot settle. But it is not so bad to mistake in data, as in data and inferences both. It is better to guess at only one thing than at two.

The first example I shall now give of the application of my rules is of rails substantially like those used on the Pennsylvania Railroad, the minimum weight being supposed to be 100 tons to the mile (= 63.636 pounds per yard). I have supposed that 15 tons per mile (= 9.666 pounds per yard) may safely be worn off, leaving the residuary rails 85 tons to the mile (= 53.97 pounds per yard). This will leave the area of what is left of the head somewhat less than the area of the base, and will carry the

heaviest machinery now coming into use. Wearing off 15 tons per mile would wear down the head about 0.45 of an inch, or each ton about 0.03.

I assume, of course, that where the rails are made heavier the whole additional metal is put upon the head, where all the wear comes. Little or nothing is gained by adding to the base and stem that are strong enough already.

I have estimated such rails laid down ready for use at $66.666 per ton or $6 666. per mile. Each additional stratum on the top of the rail, about 0.09 of an inch thick, weighing 3 tons per mile, will, then, cost $200.

Supposing prices continue the same, the renewal will cost $6 666. per mile, from which deduct the value of the old rails, and to which add the proper charge for detentions and inconveniences. I have estimated it for a track of 100 tons to the mile at $3 550, with an increase of $200 for each 3 tons per mile.

If, by the time of renewal, rails fall $10 per ton in price, then the loss on renewal will be lessened $1 000 by lower price of new rails, and increased $566 ($= \frac{2}{3} \times 10 \times 85$) by less price for old rails, making it $3 116. This will be represented by L_1. Each 3 tons weight of rails adds to this $170.

Or, if the rails should decline in price $20 per ton, the loss on renewal would be reduced $2 000 per mile, by less cost of new rails, and increased $1 133 ($= \frac{2}{3} \times 20 \times 85$) by less price for old rails, making $2 683. This will be represented by L_2. Each additional 3 tons increases it $140.

The economic values of V used in these calculations vary with the opportunities of usefulness, or saving expense, as follows :

	Interest.		
	5 Per Cent.	6 Per Cent.	7 Per Cent.
With prices constant V=.....	$12 222	$11 070	$10 252
With decline of $10 per ton V_1 =.....	11 542	10 532	9 813
With decline of $20 per ton V_2 =.....	10 865	9 995	9 376

I have appended tables showing the details of the data assumed, the steps of the calculations, and the results with different rates of interest, and under the different circumstances heretofore mentioned. I have also appended profiles showing the amount of saving by increase of weight.

It will be seen from the tables of results, and from the culminating points of the profiles, that where a 63⅔ pounds rail will last only 10 years, there is a decided gain in so increasing the weight that it shall last from 18 to 26 years. This is shown by the following synopsis. The greater part of the gain, however, is obtained by an increase much short of the maximum gain :

Absolutely Greatest Saving.						Approaching Greatest Saving.			
Rate of Interest.	*T* Years.	Wt. per Mile, Tons.	Wt. per Yd., Lbs.	Fall in Price of Rails.	Saving.	*T*.	Wt. Tons.	Wt. Lbs.	Saving.
5 Per Cent.	26	124	78.9	$ 0	$1 984	22	118	75.1	$1 937
"	24	121	77.	10	1 581	20	115	73.2	1 522
"	22	118	75.1	20	1 205	20	115	73.2	1 191
6 Per Cent.	22	118	75.1	0	1 416	20	115	73.2	1 393
"	22	118	75.1	10	1 118	18	112	71.3	1 066
"	20	115	73.2	20	833	18	112	71.3	820
7 Per Cent.	20	115	73.2	0	1 049	18	112	71.3	1 010
"	20	115	73.2	10	807	18	112	71.3	798
"	18	112	71.3	20	586	16	109	69.4	564

We should not miss it much by saying that on a road where a 63⅔ pounds rail will wear only 10 years, the most economical size is about 72 pounds per yard, but that two-thirds of the greatest gain is attained by increasing to 67 pounds per yard.

One objection to such a rail is the increased disproportion between the head and base, increasing the difficulty of cooling without strain, after rolling.

Other considerations, which it is not my present purpose to refer to, will in many cases control.

The largest traffic, heaviest machinery, lowest interest, and greatest inconvenience of renewal call for the heaviest rail, the smaller traffic, lighter machinery, higher interest, and probable future decline in the price of rails call for lighter rails.

All these calculations contemplate constant traffic. If it increases, as is in most cases probable, it is an argument in favor of heavier rails.

Though the weight of rail and the time of greatest saving is so near the same in all cases, the amount of saving by increased weight varies very much. The lowest interest and highest future price give the greatest saving. At 5 per cent. and prices constant, the greatest saving is $1 984, with future prices $20 lower, $1 205. At 6 per cent. and prices constant, the greatest saving $1 426, or with decline of $20, $833. At 7 per cent. and prices constant, the greatest saving is $1 049, or with decline of $20, $567.

I have added a table to show what gain there is, in increasing the size of $63\frac{2}{3}$ lb. rail on a road where it will last twenty years. Even with money at 5 per cent. and prices constant, the gain by increase is small, and when money is 7 per cent. and prices decline $20, there is no gain.

I may be asked why I have adopted, as an example, a rail whose residuary portion is 53 lbs., when, in 1867, I laid 53 lb. steel rails on the main line between New York and Philadelphia, which were only taken out in 1880, and some of which were worn down to 46 lbs. per yard; and when 56 lb. rails were laid on the line between Philadelphia and Baltimore, in 1868, and are still in the track, and after the lapse of a dozen years, are still in good order, and when on another road, 56 lb. rails now carrying 100 000 tons of coal per month, are worn down to 45 to 46 lbs. per yard, and when many important lines are laid with 56 lb. rails.

My answer is, that the increasing weight of machinery and of the loads carried have induced the great trunk lines to adopt the heavier rail. The maximum weight on a freight car wheel has been increased from 5 000 to 8 000 lbs., and on a locomotive driving wheel from 10 000 to 15 000 lbs., or even more. It seemed, therefore, proper that our example should be taken from this heavy class. But I have also given calculations for the 53 lb. rail.

If as good steel can be got now as formerly, a road of moderate traffic may be laid with 53 lb. rails. But the machinery must be adapted to it.

It will not do for a committee of the directors to buy an engine and put it on the road, because it will haul a big load, without knowing whether the rails are strong enough to carry it or not.

A size of rail which it was wise to adopt a few years ago, when American companies paid full 7 per cent. interest, when money was scarce, credit poor, traffic small, machinery and loads light, speeds slower, steel high but falling in price and, perhaps, in quality, it might be unwise to adopt now on great thoroughfares, when all these circumstances are reversed.

Suppose a rail 53.03 pounds to the yard = 83.33 tons to the mile, and on a road where it will last ten years, losing in that time 1.125 tons per year, or 11.25 tons in all ; and leaving the residuary rail 72.08 tons per mile = 45.87 lbs. per yard. It will thus wear down about 0.0333 inches per year, and lose 0.716 lbs. per yard per year, or 7.16 in all.

If prices remain constant, and rails cost 66.66 per ton in finished tracks, the additional cost to make it last two additional years is $150 per mile, and the increased cost of renewal the same. If the price of rails falls $10 per ton, the cost of renewal is reduced from $3 000 to 2 647 per mile, with an increase of $125 for metal for each two years additional duration. If prices decline $20 per ton, the cost of renewal is reduced to $2 294, with an increase of $100 for metal to increase the durability two years. All which is shown in the tables.

Thus far I have supposed each kind of rails to be perpetuated. Now, suppose the $63\frac{2}{3}$ lb. rails before considered, instead of being perpetuated, are only renewed one, two or three times. The loss on renewal being $3 550, the cost of it is 3 116. The present value of the cost of renewal is $3\ 116 \div 1 + a$. In the following table the first column is years ; the second, cost of rail that will last those years ; the third and sixth, present value of cost of renewal of rails that last ten years ; the fourth and seventh, the aggregate of all cost of short lived rails ; the fifth and eighth, the saving on the long lived rails.

T Years.	Cost of Rails Lasting those Years.	Interest, 5 per cent.			Interest 7 per cent.		
		Pr. Value Cost of Renewal.	Aggregate Pr. Value of all cost Short Lived Rails.	Gain by Larger Rails.	Pr. Value of Cost of Renewal.	Pr. Value all Cost of Smaller Rails.	Gain by Larger Rails.
10	6 666	.....	6 666	.....	.....	6 666	.....
20	7 666	1 902	8 568	902	1 569	8 235	569
30	8 666	1 160	9 728	1 062	787	9 022	356
40	9 666	440	10 168	502	396	9 418	— 248

The cases supposed and inferences from them, are given as examples of the application of rules that are very simple, and that I have found very convenient. They also show some striking results. They are applicable in the comparison of many cheap and short lived things with more costly and durable things, between which the engineer is often called to choose—such as wooden and iron bridges. To save a good deal of labor to those who wish to use these rules, I have appended a table of the rates of accumulated interest at 5, 6, and 7 per cent.

Symbols used in the following tables :

Capital letters used to represent the $63\frac{2}{3}$ lb. rails, and for distinction, small letters to represent the 53 lb. rails.

a. Rate of accumulated interest.

d. Depth of consumable part of head.

w. Weight in tons per mile.

T. Time the rails will last.

C. Cost per mile laid.

L. Loss per mile on renewal if prices constant.

L_1. Loss on renewal if price declines \$10 per ton.

L_2. Loss on renewal if price declines \$20 per ton.

R. Real value per mile of enlarged rails, prices constant.

R_1. Real value if price declines \$10 per ton.

R_2. Real value if price declines \$20 per ton.

S. Saving by enlarging rails $= R - C^1$, price constant.

S_1. Saving if price declines \$10, $= R_1 - C^1$.

S_2. Saving if price declines \$20, $= R_2 - C^1$.

TABLE 1.—DATA ASSUMED WITH THE $63\frac{2}{3}$ LB. RAILS, WHERE THEY WILL LAST TEN YEARS, AND THEN BE REDUCED IN WEIGHT 15 PER CENT. FOR MEANING OF SYMBOLS SEE P. 261.

$T.$	$d.$	$w.$	$C.$	$L.$	$L_1.$	$L_2.$
10	0.45	100	6666	3550	3116	2683
12	0.54	103	6866	3750	3286	2823
14	0.63	106	7066	3950	3456	2963
16	0.72	109	7266	4150	3626	3103
18	0.81	112	7466	4350	3796	3243
20	0.90	115	7666	4550	3966	3383
22	0.99	118	7866	4750	4136	3523
24	1.08	121	8066	4950	4306	3663
26	1.17	124	8266	5150	4476	3803
28	1.26	127	8466	5350	4646	3943
30	1.35	130	8666	5550	4816	4083
32	1.44	133	8866	5750	4986	4223
34	1.53	136	9066	5950	5156	4363
36	1.62	139	9266	6150	5326	4503
38	1.71	142	9466	6350	5496	4643
40	1.80	145	9666	6550	5666	4783
44	1.98	151	10066	6950	6006	5063
48	2.16	157	10466	7350	6346	5343
52	2.34	163	10866	7750	6686	5623
56	2.62	169	11266	8150	7026	5903
60	2.70	175	11666	8550	7366	6183

TABLE 2.—CALCULATIONS OF THE $63\frac{2}{3}$ LB. RAILS. INTEREST 5 PER CENT.

T.	a	$\frac{L}{a}$	$\frac{L_1}{a}$	$\frac{L_2}{a}$
10	0.639	5556	4876	4199
12	0.808	4641	4067	3494
14	0.996	3966	3470	2975
16	1.204	3447	3012	2577
18	1.432	3038	2651	2265
20	1.685	2700	2354	2008
22	1.964	2419	2106	1794
24	2.272	2179	1895	1612
26	2.611	1972	1714	1457
28	2.986	1792	1556	1320
30	3.400	1632	1416	1201
32	3.857	1491	1293	1095
34	4.361	1364	1182	1000
36	4.917	1251	1083	916
38	5.532	1148	993	839
40	6.210	1055	912	770
42	6.956	970	839	708
44	7.784	893	772	650
46	8.696	822	710	598
48	9.703	757	654	551
50	10.814	698	603	507
52	12.040	644	555	467
54	13.394	594	512	430
56	14.888	547	472	396
58	16.538	505	435	365
60	18.358	466	401	337

TABLE 3.--CALCULATIONS WITH THE $63\frac{2}{3}$ LB. RAILS. INTEREST 6 PER CENT.

T	a	$\frac{L}{a}$	$\frac{L_1}{a}$	$\frac{L_2}{a}$
10	0.806	4404	3866	3329
12	1.033	3630	3181	2733
14	1.288	3067	2683	2300
16	1.575	2635	2302	1970
18	1.898	2292	2000	1709
20	2.262	2011	1753	1496
22	2.671	1778	1548	1319
24	3.132	1580	1375	1170
26	3.651	1411	1226	1042
28	4.235	1263	1097	931
30	4.892	1135	984	835
32	5.631	1021	885	750
34	6.463	921	798	675
36	7.400	831	720	609
38	8.454	751	650	549
40	9.641	679	588	496
42	10.976	615	532	449
44	12.480	557	481	406
46	14.171	505	436	367
48	16.076	457	395	332
50	18.219	414	358	301
52	20.63	376	324	273
54	23.345	341	294	247
56	26.401	309	266	224
58	29.84	280	241	203
60	33.711	254	219	183

TABLE 4.—CALCULATIONS WITH THE $63\frac{2}{3}$ LB. RAILS. INTEREST 7 PER CENT.

T	a	$\frac{L}{a}$	$\frac{L_1}{a}$	$\frac{L_2}{a}$
10	0.990	3586	3147	2710
12	1.283	2923	2561	2200
14	1.620	2438	2133	1829
16	2.007	2068	1807	1546
18	2.450	1776	1549	1324
20	2.960	1537	1340	1143
22	3.543	1341	1167	994
24	4.214	1175	1022	869
26	4.983	1034	898	763
28	5.865	912	792	672
30	6.878	807	700	594
32	8.040	715	620	525
34	9.374	635	550	465
36	10.904	564	488	413
38	12.66	502	434	367
40	14.676	446	386	326
42	16.988	397	344	290
44	19.642	354	306	258
46	22.687	315	272	229
48	26.181	281	242	204
50	30.191	250	216	182
52	34.792	223	192	162
54	40.073	198	171	144
56	46.132	177	152	128
58	53.085	157	136	114
60	61.063	140	121	101

TABLE 5.—Results with the $63\frac{2}{3}$ lb. Rails. Interest 5 per cent.

T	C	R	$S = R - C'$	R_1	$S_1 = R_1 - C'$	R_2	$S_2 = R_2 - C'$
10	6666	6666					
12	6866	7581	715	7475	609	7371	505
14	7066	8256	1190	8072	1006	7890	824
16	7266	8775	1509	8530	1264	8288	1022
18	7466	9184	1718	8891	1425	8600	1134
20	7666	9522	1856	9188	1522	8857	1191
22	7866	9803	1937	9436	1570	9071	1205
24	8066	10043	1977	9647	1581	9253	1187
26	8266	10250	1984	9828	1562	9408	1142
28	8466	10430	1964	9986	1520	9545	1079
30	8666	10590	1924	10126	1460	9664	998
32	8866	10731	1865	10249	1383	9770	904
34	9066	10858	1792	10360	1294	9865	799
36	9266	10971	1705	10459	1193	9949	683
38	9466	11074	1608	10549	1083	10026	560
40	9666	11167	1501	10630	964	10095	429
42	9866	11252	1386	10703	837	10157	291
44	10066	11329	1263	10770	704	10215	149
46	10266	11400	1134	10832	566	10267	1
48	10466	11465	999	10888	422	10314	—152
50	10666	11524	858	10939	273	10358	—308
52	10866	11578	712	10987	121	10398	—468
54	11066	11628	562	11030	—36	10435	—631
56	11266	11675	409	11070	—196	10469	—797
58	11466	11717	251	11107	—359	10500	—966
60	11666	11756	90	11141	—525	10528	—1138

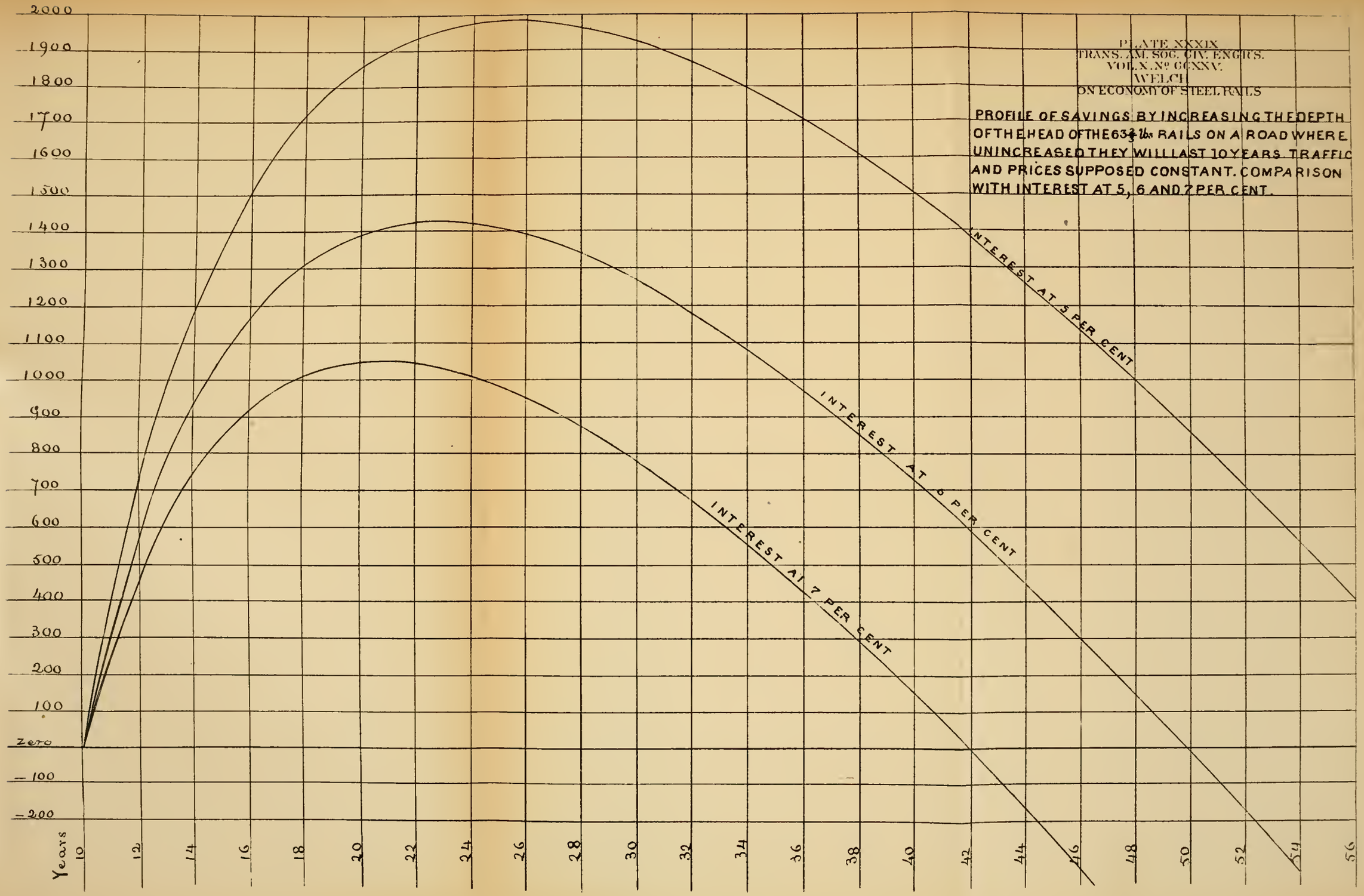
PLATE XXXIX
TRANS. AM. SOC. CIV. ENGRS.
VOL. X. No. CCXXV.
WELCH
ON ECONOMY OF STEEL RAILS
PROFILE OF SAVINGS BY INCREASING THE DEPTH OF THE HEAD OF THE 63½ lb. RAILS ON A ROAD WHERE UNINCREASED THEY WILL LAST 10 YEARS. TRAFFIC AND PRICES SUPPOSED CONSTANT. COMPARISON WITH INTEREST AT 5, 6 AND 7 PER CENT.
INTEREST AT 5 PER CENT
INTEREST AT 6 PER CENT
INTEREST AT 7 PER CENT
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
zero
-100
-200
Years
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TABLE 6.—Results with the $63\frac{2}{3}$ lb. rails. Interest 6 per cent.

T	C	R	$S = R - C'$	R_1	$S_1 = R_1 - C'$	R_2	$S_2 = R_2 - C'$
10	6666	6666					
12	6866	7440	574	7351	485	7262	396
14	7066	8003	937	7849	783	7695	629
16	7266	8435	1169	8230	964	8025	759
18	7466	8778	1312	8532	1066	8286	820
20	7666	9059	1393	8779	1113	8499	833
22	7866	9292	1426	8984	1118	8676	810
24	8066	9490	1424	9157	1091	8825	759
26	8266	9659	1393	9306	1040	8953	687
28	8466	9807	1341	9435	969	9064	598
30	8666	9935	1269	9548	882	9160	494
32	8866	10049	1183	9647	781	9245	379
34	9066	10149	1083	9734	668	9320	254
36	9266	10239	973	9812	546	9386	120
38	9466	10319	853	9882	416	9446	—20
40	9666	10391	725	9944	278	9499	—167
42	9866	10455	589	10000	134	9546	—320
44	10066	10513	447	10051	—15	9589	—477
46	10266	10565	299	10096	—170	9628	—638
48	10466	10613	147	10137	—329	9663	—803
50	10666	10656	—10	10174	—492	9694	—972
52	10866	10694	—172	10208	—658	9722	—1144
54	11066	10729	—337	10238	—828	9748	—1318
56	11266	10761	—505	10266	—1000	9771	—1495
58	11466	10790	—676	10291	—1175	9792	—1674
60	11666	10816	—850	10313	—1353	9812	—1854

TABLE 7.—Results with the $63\frac{2}{3}$ lb. Rails. Interest 7 per cent.

T	C	R	$S = R - C'$	R_1	$S_1 = R_1 - C'$	R_2	$S_2 = R_2 - C'$
10	6666	6666	.....	.....	.....	.....	.....
12	6866	7329	463	7252	386	7176	310
14	7066	7814	748	7680	614	7547	481
16	7266	8184	918	8006	740	7830	564
18	7466	8476	1010	8264	798	8052	586
20	7666	8715	1049	8473	807	8233	567
22	7866	8911	1045	8646	780	8382	516
24	8066	9077	1011	8791	725	8507	441
26	8266	9218	952	8915	649	8613	347
28	8466	9340	874	9021	555	8704	238
30	8666	9445	779	9113	447	8782	116
32	8866	9537	671	9193	327	8851	—15
34	9066	9617	551	9263	197	8911	—155
36	9266	9688	422	9325	59	8963	—303
38	9466	9750	284	9379	—87	9009	—457
40	9666	9806	140	9427	—239	9050	—616
42	9866	9855	—11	9469	—397	9086	—780
44	10066	9898	—168	9507	—559	9118	—948
46	10266	9937	—329	9541	—725	9147	—1119
48	10466	9971	—495	9571	—895	9172	—1294
50	10666	10002	—664	9597	—1069	9194	—1472
52	10866	10029	—837	9621	—1245	9214	—1652
54	11066	10054	—1012	9642	—1424	9232	—1834
56	11266	10075	—1191	9661	—1605	9248	—2018
58	11466	10095	—1371	9677	—1789	9262	—2204
60	11666	10112	—1554	9692	—1974	9275	—2391

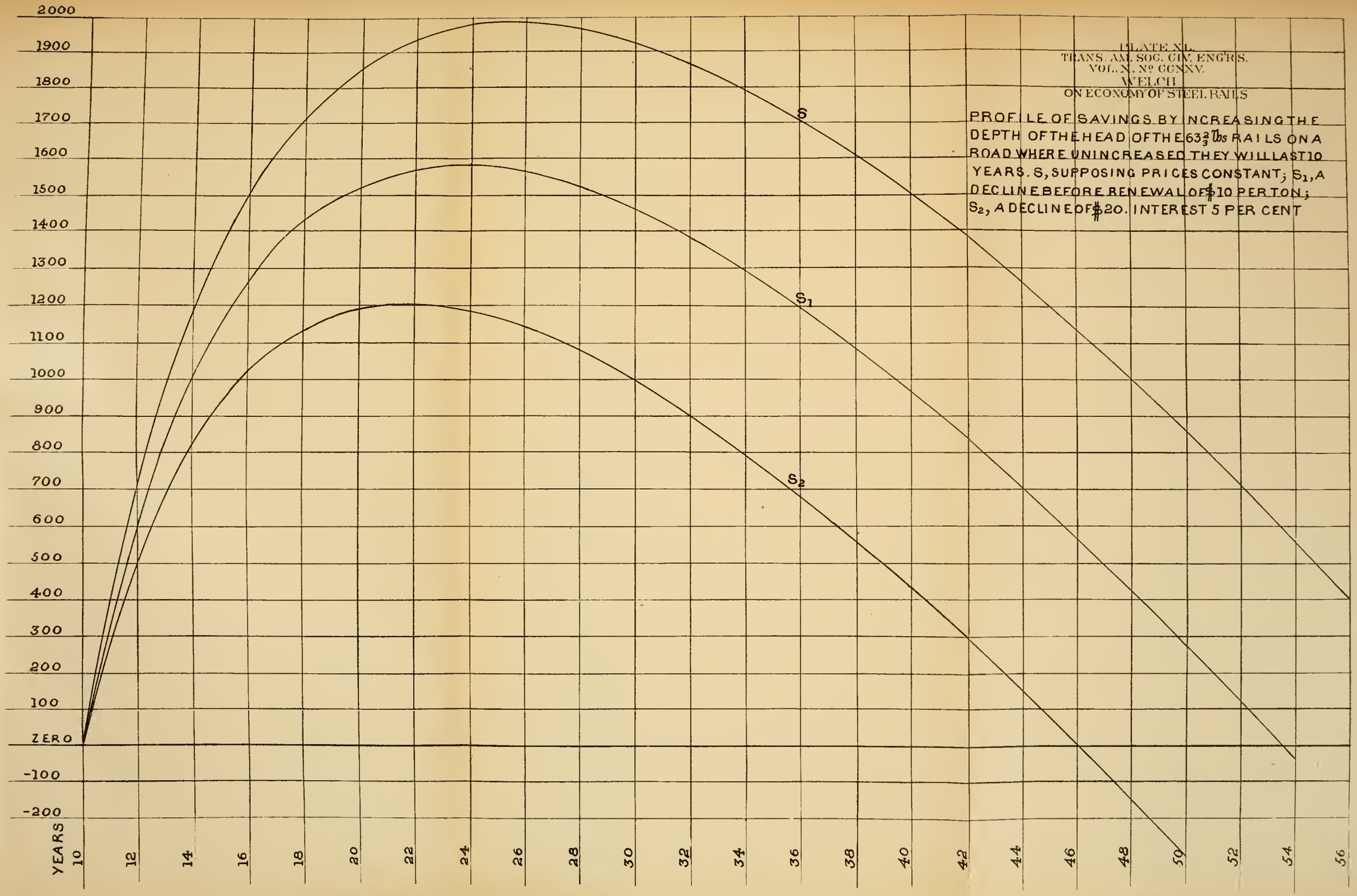
PROFILE OF SAVINGS BY INCREASING THE DEPTH OF THE HEAD OF THE 63⅔ lbs RAILS ON A ROAD WHERE UNINCREASED THEY WILL LAST 10 YEARS. S, SUPPOSING PRICES CONSTANT; S1, A DECLINE BEFORE RENEWAL OF $10 PER TON; S2, A DECLINE OF $20. INTEREST 5 PER CENT
S
S1
S2
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
ZERO
-100
-200
YEARS
10
12
14
16
18
20
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TABLE 8.—Results with Prices Constant where a $63\frac{2}{3}$ lb. Rail lasts 20 Years.

$V = 8779.$

T	a	L	$\frac{L}{a}$	R	C	S	
20	1.68	3550	2113	.....	6666	.....	Interest 5 per cent.
24	2.27	3750	1582	7197	6866	331	
28	2.99	3950	1321	7458	7066	392	
32	3.86	4150	1075	7704	7266	438	
36	4.92	4350	884	7895	7466	429	
40	6.21	4550	733	8046	7666	380	
44	7.78	4750	610	8169	7866	303	
48	9.70	4950	510	8269	8066	203	

$V = 8237.$

20	2.26	3550	1571	.....	6666	.....	Interest 6 per cent.
24	3.13	3750	1198	7037	6866	171	
28	4.23	3950	934	7303	7066	237	
32	5.63	4150	737	7500	7266	234	
36	7.40	4350	584	7653	7466	187	
40	7.64	4550	473	7764	7666	98	
44	12.48	4750	380	7857	7866	— 9	
48	16.08	4950	308	7929	8066	—137	

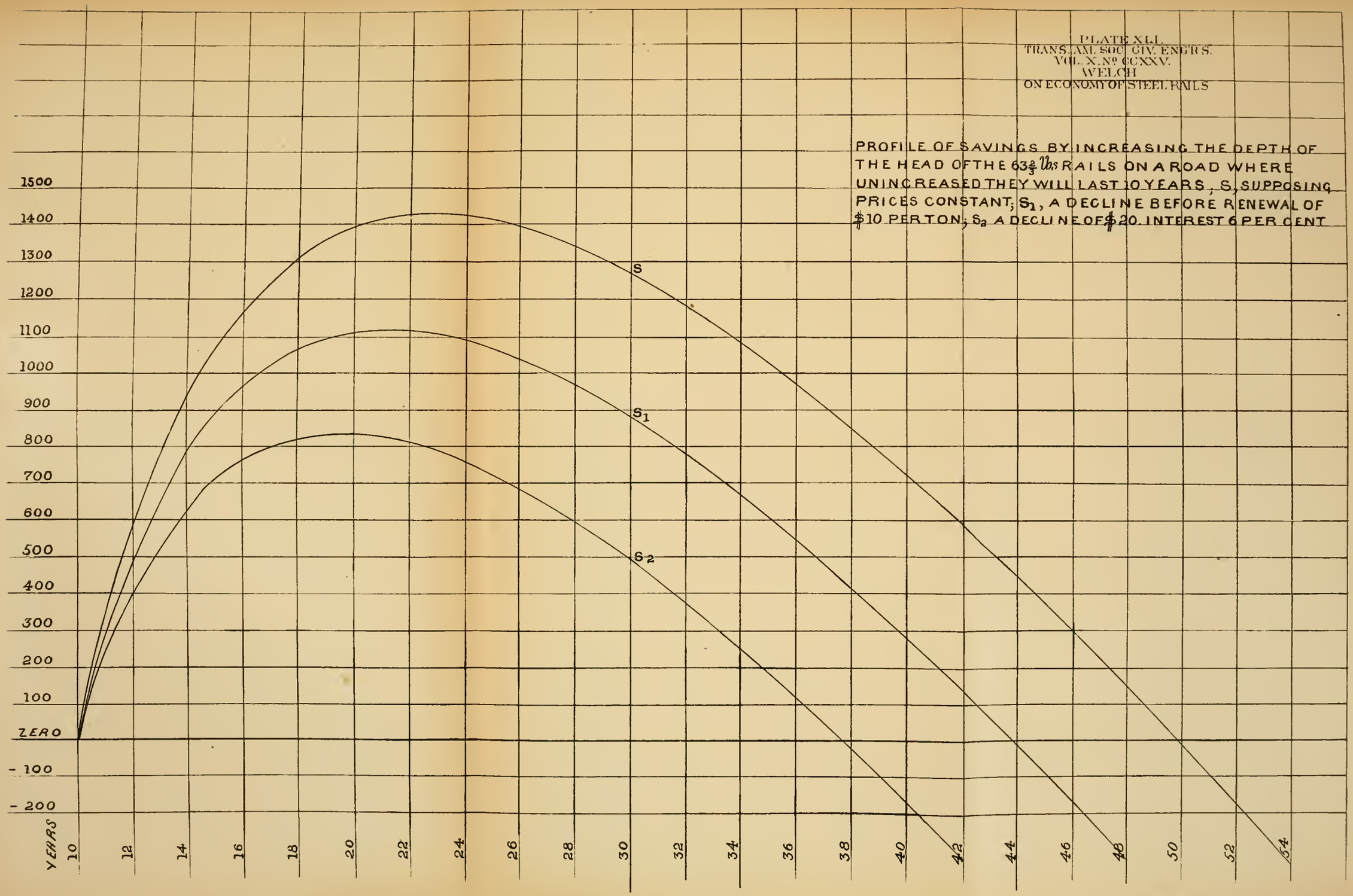
$V = 7866.$

20	2.96	3550	1200	.....	6666	.....	Interest 7 per cent.
24	4.21	3750	891	6973	6866	109	
28	5.87	3950	673	7193	7066	127	
32	8.04	4150	516	7350	7266	84	
36	10.90	4350	400	7466	7466	0	
40	14.68	4550	300	7566	7666	—100	
44	19.64	4750	242	7624	7866	—242	

TABLE 9.—RESULTS—RAIL OF $63\frac{2}{3}$ LBS. LASTING 20 YEARS. INTEREST 7 PER CENT. DECLINE $20.

$V = 7569.$

T	W	a	L_2	$\frac{L_2}{a}$	R_2	C	S_2
20	100	2.96	2683	903	.....	6666	.....
24	103	4.21	2823	670	6899	6866	33
28	106	5.87	2963	504	7065	7066	—1
32	109	8.04	3103	386	7183	7266	—83
36	112	10.90	3243	300	7269	7466	—197
40	115	14.68	3383	230	7339	7666	—327


PROFILE OF SAVINGS BY INCREASING THE DEPTH OF THE HEAD OF THE 63⅔ lbs RAILS ON A ROAD WHERE UNINCREASED THEY WILL LAST 10 YEARS, S, SUPPOSING PRICES CONSTANT; S1, A DECLINE BEFORE RENEWAL OF $10 PER TON; S2 A DECLINE OF $20. INTEREST 6 PER CENT
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
ZERO
- 100
- 200
YEARS
10
12
14
16
18
20
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24
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36
38
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44
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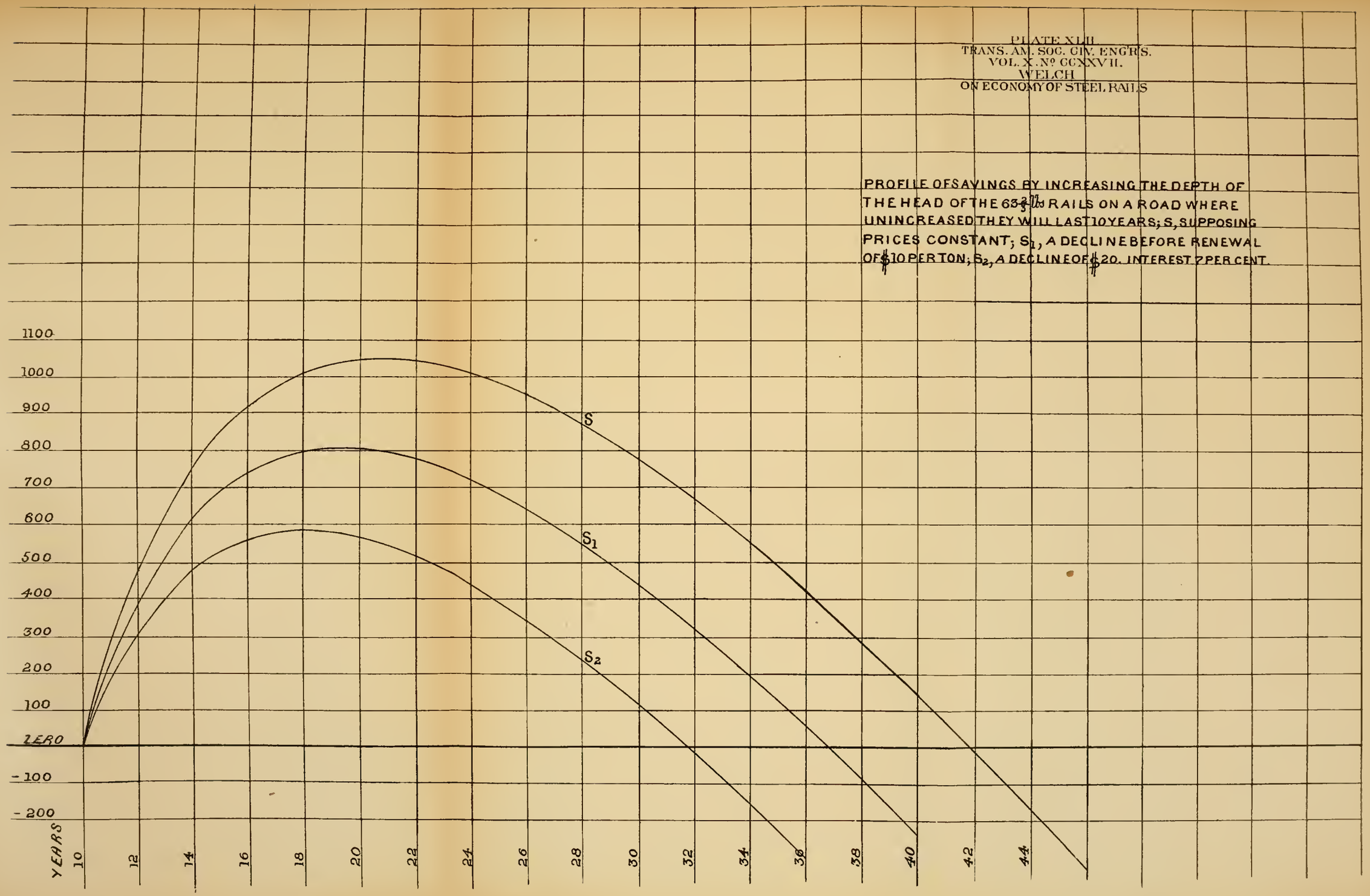
50
52
54
S
S1
S2

TABLE 10.—DATA WITH 53.03 LB. RAIL—LASTS 10 YEARS—RESIDUARY 45.87 LBS.

$T.$	$d.$	$w.$	$c.$	$l.$	$l._1$	$l_2.$
10	.333	83.33	5555	3000	2647	2294
12	.400	85.58	5705	3150	2777	2394
14	.466	87.83	5855	3300	2897	2494
16	.533	90.08	6005	3450	3022	2594
18	.600	92.33	6155	3600	3147	2694
20	.666	94.58	6305	3750	3272	2794
22	.733	96.83	6455	3900	3397	2894
24	.800	99.08	6605	4050	3522	2994
26	.866	101.33	6755	4200	3647	3094
28	.933	103.58	6905	4350	3772	3194
30	1.000	105.83	7055	4500	3897	3294
32	1.066	108.08	7205	4650	4022	3394
34	1.133	110.33	7355	4800	4147	3494
36	1.200	112.58	7505	4950	4272	3594
38	1.266	114.83	7655	5100	4397	3694
40	1.333	117.08	7805	5250	4522	3794
42	1.400	119.33	7955	5400	4647	3894
44	1.466	121.58	8105	5550	4772	3994
46	1.533	123.83	8255	5700	4897	4094
48	1.600	126.08	8405	5850	5022	4194
50	1.666	128.33	8555	6000	5147	4294

TABLE 11.—CALCULATIONS 53.03 LB. RAIL. INTEREST 5 PER CENT.

T	a	$\frac{l}{a}$	$\frac{l_1}{a}$	$\frac{l_2}{a}$	
10	0.639	4695	4142	3590	$c =$ 5,555
12	0.808	3899	3431	2963	$v =$ 10,250
14	0.996	3313	2909	2504	$v_1 =$ 9,697
16	1.204	2865	2510	2154	$v_2 =$ 9,145
18	1.432	2514	2198	1881	
20	1.685	2226	1942	1657	
22	1.964	1986	1730	1473	
24	2.272	1783	1550	1318	
26	2.611	1609	1397	1185	
28	2.886	1457	1263	1070	
30	3.400	1324	1146	969	
32	3.857	1206	1043	880	
34	4.361	1101	951	801	
36	4.917	1007	869	731	
38	5.532	922	795	668	
40	6.210	845	728	611	
42	6.956	776	668	560	
44	7.784	713	613	513	
46	8 696	656	563	471	
48	9.703	603	518	432	
50	10.814	555	476	397	


PROFILE OF SAVINGS BY INCREASING THE DEPTH OF THE HEAD OF THE 63 3/5 lbs RAILS ON A ROAD WHERE UNINCREASED THEY WILL LAST 10 YEARS; S, SUPPOSING PRICES CONSTANT; S1, A DECLINE BEFORE RENEWAL OF $10 PER TON; S2, A DECLINE OF $20. INTEREST 7 PER CENT.
1100
1000
900
800
700
600
500
400
300
200
100
ZERO
-100
-200
YEARS
10
12
14
16
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42
44
S
S1
S2

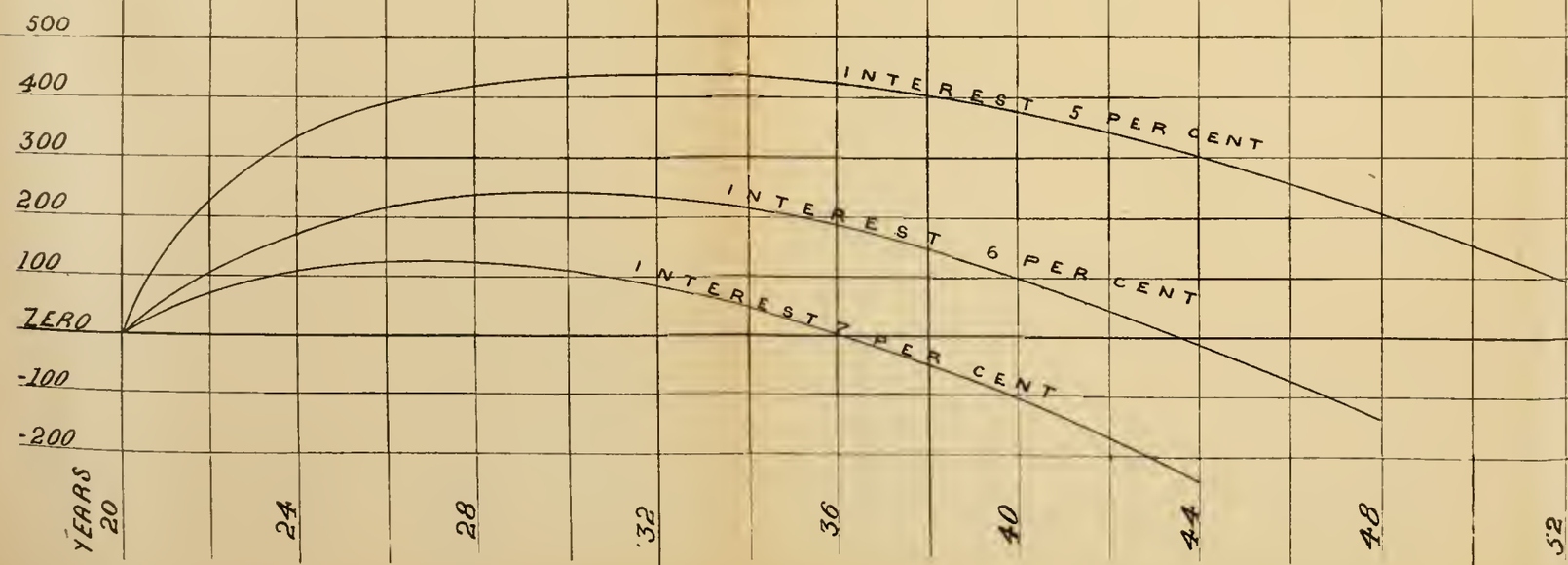
TABLE 12.—TABLE OF RESULTS WITH 53.03 LB. RAILS.—INTEREST 5 PER CENT.

T	$c.$	r	$s = r - c$	r_1	$s_1 = r_1 - c'$	r_2	$s_2 = r_2 - c'$
10	5555						
12	5705	6351	646	6266	561	6182	477
14	5855	6937	1082	6788	933	6641	786
16	6005	7385	1380	7187	1182	6991	986
18	6155	7736	1581	7499	1344	7264	1109
20	6305	8024	1719	7755	1450	7488	1183
22	6455	8264	1809	7967	1512	7672	1217
24	6605	8467	1862	8147	1542	7827	1222
26	6755	8641	1886	8300	1545	7960	1205
28	6905	8793	1888	8434	1529	8075	1170
30	7055	8926	1871	8551	1496	8176	1121
32	7205	9044	1839	8654	1449	8263	1060
34	7355	9149	1794	8746	1391	8344	989
36	7505	9243	1738	8828	1323	8414	909
38	7655	9328	1673	8902	1247	8477	822
40	7805	9405	1600	8969	1164	8534	729
42	7955	9474	1519	9029	1074	8585	630
44	8105	9537	1432	9084	979	8632	527
46	8255	9594	1339	9134	879	8674	419
48	8405	9647	1242	9179	774	8713	308
50	8555	9695	1140	9221	666	8748	193

TABLE 13.—RATES OF ACCUMULATED INTEREST.

	5 *p. c.*	6 *p. c.*	7 *p. c.*		5 *p. c.*	6 *p. c.*	7 *p. c.*
½	0.0250	0.0300	0.0350	42	6.9562	10.9760	16.988
1	0.0506	0.0609	0.0712	44	7.7842	12.4800	19.642
2	0.1038	0.1255	0.1475	46	8.6961	14.171	22.687
4	0.2184	0.2668	0.3168	48	9.703	16.076	26.181
6	0.3449	0.4258	0.5111	50	10.814	18 219	30.191
8	0.4845	0.6047	0.7340				
10	0.6386	0.8061	0.9898	60	18.358	33.711	61.063
12	0.8087	1.0328	1.2833	70	30.721	61.691	122.49
14	0.9965	1.2879	1.6202	80	50.979	112.23	244.72
16	1.2038	1 5751	2.0067	90	84.173	203.50	487.94
18	1.4325	1.8983	2.4503	100	138.57	368.35	971.88
20	1.6851	2.2620	2.9593				
22	1.9638	2.6714	3.5433				
24	2.2715	3.1322	4.2136				
26	2.6111	3.6509	4.9827				
28	2.9860	4.2346	5.8653				
30	3.3998	4.8916	6.8780				
32	3.8566	5.6310	8.0402				
34	4.3607	6.4633	9.3740				
36	4.9173	7.4000	10.9040				
38	5.5316	8.4543	12.6600				
40	6.2096	9.6410	14.6760				

PROFILE OF SAVINGS BY INCREASING THE DEPTH OF THE HEAD OF THE 63⅔ lbs RAILS ON A ROAD WHERE UNINCREASED THEY WILL LAST 20 YEARS. TRAFFIC AND PRICES SUPPOSED CONSTANT. COMPARISON WITH INTEREST AT 5, 6 AND 7 PER CENT.



AMERICAN SOCIETY OF CIVIL ENGINEERS.

TRANSACTIONS.

CCXXVI.

Vol. X.—August, 1881.

QUICKSAND IN EXCAVATION.

By Charles L. McAlpine, Member of the Society.

Read May 18, 1881.

WITH DISCUSSION

By William R. Hutton, Member of the Society.

Particular attention has been given, and expressed by members of the Society and others, in writing, and orally, as to the various materials encountered in the prosecution of work; yet little has been recorded of the material of which this paper is the subject.

The various text-books are silent in regard to the economic management of this, one of the most troublesome materials that an engineer is called upon to deal with.

Those who have encountered it would have been greatly aided by the experience, now only contained in private note-books or the recollections of the profession.

With this in view, the writer offers to the Society some memoranda and a description of the methods used several years since, in the excavation and removal of a large body of quicksand, prefacing that two energetic and experienced contractors successively failed in their attempts by the ordinary methods used for removing earth excavation.

As these failures had given the place a bad name among contractors, and no one was found willing, except at excessive prices, to undertake the work, the writer, then in charge, urged and obtained from the State authorities of New York the power to conduct it personally.

Omitting mention of minor difficulties, only the principal ones will be here considered.

A mass of quicksand occurred in a cutting on the State works of New York, of about thirteen hundred feet in length, and averaging about thirty feet in depth, amounting in the aggregate to one hundred thousand cubic yards—although a portion of the cutting was what is known as cemented clay and gravel (sometimes called hard-pan), occurring in layers or strata at different elevations, the remainder being ordinary earth excavation.

About forty thousand cubic yards had been removed by the contractor, or was other than quicksand, leaving sixty thousand cubic yards of the latter material.

No change of location was admissible.

The contractors' methods had been to work off as much material as possible at the ends and top of the cutting, using heavy plows, especially constructed, requiring in some cases eight to ten horses in order to break it up for the shovel. Some attention had been also paid to drainage.

A breast and falls had been attempted at one end, in the usual manner for ordinary earth, but the material remained quicksand, despite some attempts to reduce it to a less expensive condition.

It was no infrequent occurrence to see laborers, animals, contractor and engineers stuck fast in the mud together—some of them extracted with no little difficulty—and a visitor to this section always brought away with him distinguishing marks of his trip.

When the execution of the work passed into the hands of the engineer, the key-note was considered to be a most thorough and complete system of drainage, as nearly all of the difficulties met with were directly traceable to the excessive amount of water which this

peculiar material is capable of retaining, and drawing to itself through capillary attraction or other natural laws, and which it very reluctantly parts with.

Although its name conveys the idea of a mass of sand, surcharged with water until it becomes "quick," or susceptible of easy movement or agitation, suggesting actual life, yet engineers know only too well that this is not the most troublesome member of the family.

The one that causes the most trouble, and is here treated of, is an argillaceous material containing no silex or grit, comminutes completely, and is usually leaden in color in its natural state, and nearly white when thoroughly deprived of water.

So free is it from sand that it can be used with good effect in polishing or cleaning silver and the softer metals.

The work was therefore commenced by driving a cutting into the middle of the quicksand and at right angles to the canal prism, with a grade below canal bottom, and amply below the level necessary for good and rapid drainage.

The comparative magnitude of this drainage cutting, amounting to nine thousand cubic yards, to be made at their own cost, had deterred the contractors from attempting it.

To this main drain other large ones were conducted, over the surface of the cutting intended for the prism.

The top width of the prism cutting was about one hundred and fifty feet.

Connecting with these large drains were innumerable smaller ones, made to reach all parts of the surface of the quicksand.

Such drainage as could be effected from each end of the cutting was also availed of.

The construction and maintenance of these ditches, in first rate effective order, was in reality the key to the success of the plan, but with continued practice it was remarkable how efficient the workmen became in this troublesome part of the work.

By an occasional judicious use of the plow or scraper, but mainly, however, with spades and shovels, providing planks for the men to stand on while at work, and the selection of intelligent workmen, the cost and time required were soon much reduced.

As far as possible, all traveling over the surface while being thus ditched was prevented, as it agitated the material, and caused it to retain the water more obstinately.

After a night's quiet rest, and the great withdrawal of water through the ditches, the surface was in good condition for excavating and the material, in the words of the workmen, would then "shovel like ashes."

As far as possible, plank roads were laid for the carts, and by frequently shifting from one place to another, the parts to be worked were given sufficient time to drain, and they had also been given the undisturbed *rest* which this material requires.

Care should always be had to withdraw the men and teams at once from any place which indicates that it is again becoming "quick," from the disturbing effect of repeated traveling over its surface.

Nothing is gained by working longer, when this important question of rest is involved.

It is better to stop work for the day, if no other use for the force can be provided.

A certain period of rest is as essential as the drainage itself.

The contractor alluded to claimed justly that his morning hours were the most profitable.

A lump of this quicksand, apparently dry, may very often be made "quick" by a little agitation alone.

Hard and apparently dry lumps will often become wet and pasty on their way to the dumping ground, so much so as to require additional labor to remove them from the carts.

The benefits of drainage, therefore, do not end until the material is *finally* disposed of.

It is useless to attempt excavation and hauling in wet weather, and a little time even is required after a storm, for the drains to reduce it to proper working conditions.

A close observance of the color is a very good guide as to the times for excavating it to the best advantage.

When at its best for easy and continuous shoveling, both in the case in point, and as observed elsewhere, its color was of a very light grayish tint.

When becoming disturbed by the agitation of continued travel and working it gradually deepened in color—and this became so well understood, that an ordinary workman was aware when it was prudent to change to another locality, and leave it to its required rest.

In its natural state in place, and before being disturbed by the workmen or drainage operations, the quicksand at a few inches below its

surface was compact, and offered considerable resistance to the penetration of spades or other working tools, and had a putty-like consistence.

It was free from sand or grit, and constituted the true engineers' quicksand, so-called or mis-called, where no sand enters into its composition.

The first discouraging weeks at the ditch-work were much improved upon by the remarkable increase in skill, and faithfulness, and efficiency of the men selected for this important part of the plan.*

The strong flow of water through the main ditch, with its collections from the minor ones, and through the ditches from each end of the cutting, indicated the success of the drainage operations.

The cost of excavating the quicksand at this place (exclusive of the expense of hauling beyond a moderate distance), under the circumstances related, was about nineteen cents per cubic yard, but to this must be added three and one-half cents for the cost of the great drain or cutting mentioned, and about four and one-half cents for the labor of constructing and keeping the sub-ditches and small drains throughout the cutting in good and effective condition.

This may be compared with the price at which an energetic contractor, by the common method, could *not* do the work at forty cents per cubic yard.

The saving in cost to the State was about eight thousand dollars, by the adoption of the plan which has been detailed in this paper, besides a saving of one-half in the time required to execute the work.

Portions of the quicksand excavation were so successfully treated, that at the present rates of labor they would not have cost above fourteen cents per cubic yard. And it should be stated that if the operations here detailed had been in use from the first, so as to include the whole

* One of the most discouraging and troublesome features, in the method detailed, is the apathy and indifference of the ordinary workman employed in keeping the ditches open and in good effective condition for drainage. The ditching is disagreeable, dirty and uncomfortable work, and there is a constant disposition to shirk it. The ditches are constantly filling up, sloughing in from the sides and swelling up from the bottom, and the water keeps the material in a sticky, pasty condition, exceedingly troublesome to handle or to remove from the shovel. The foreman often sympathizes and listens to the complaints of the men, and the usual "practical man" argument comes to the front. The immediate consequences of neglecting the minor ditches has little apparent force with the "practical" man. Moral suasion, deepening occasionally into some severity, and much personal supervision will probably always be necessary to success. In the case in point I was probably fortunate in the selection of the men for this work, and as stated, a few weeks showed a vast improvement in their efficiency; but it is well not to be discouraged when the very best efforts fail in accomplishing all that the manager is striving for.

body of the quicksand, the rate per cubic yard here given would have been considerably reduced.

The difference may be contrasted in time, cost and comfort, between excavating quicksand in its original condition when in place, by the ordinary methods in use for other materials, with that to which it is reduced by thorough drainage and careful management; or the difference between a man shoveling five or six cubic yards per day or about twenty in the same time.

This material which may have given so much trouble, first, to place it into the carts, next to haul it over its quaking surface, then to remove it from the carts, will, when finally disposed of on the embankment and exposed to the drying influences of complete drainage and sunshine, become so comminuted as to be carried off in clouds by the wind. In this state it is at the other extreme, and would be too dry for convenient shoveling.

In the opinion of the writer, hardly any case of quicksand excavation of any considerable amount could occur where it would not be profitable to first remove the water, even where natural drainage cannot be resorted to. The cost of pumping machinery of the power needed, worked either by hand, horse or steam, would soon pay for itself and work a magical change in the material. Even when the cost of machinery appears to add heavily to the expense of removal, yet the time saved, the comfort in doing the work, the saving in wear and tear, the greater ease in obtaining workmen, will be found profitable and far more satisfactory in all results.

On several of the works on which the writer was engaged, where the contractors paid but little attention to thorough drainage, the earth on each side settled to an extraordinary extent, laterally into the cuttings, for great distances on each side, occasioned by the slipping and flowing of substrata of quicksand in a semi-fluid state, weighted, as it was, by heavy superincumbent masses, so that several times the amount originally contained within the prism-lines had to be excavated and removed.

On one of our trunk lines of railway the grade was raised three times before the track could be laid, and the settlement of the surface on each side had then produced considerable damage to adjacent property.

It is well known, that when most of the water is removed from quicksand, it will bear quite a steep slope, as compared to the same material surcharged with water.

In these remarks the endeavor is made to separate the costs, expenses and method of excavating quicksand from that of other materials.

No small difficulty was occasioned, in the execution of the work, by encountering layers and strata of cemented or indurated clay and gravel, which interfered greatly with the plans for removing the quicksand.

These strata were not of sufficient thickness to make blasting profitable, offering much opposition to drilling, the pebbles being hard and apt to turn so as to continually present new surfaces to the drill, and they could not be passed until pulverization was to some extent or even completely effected.

The continued blows of a pick were slow in their effect, and the same was true of the heaviest hammer that a strong man could wield, or crows that two men could lift. I think power drills and a light, easily portable piling machine could have been used with good effect, drilling a line of holes a little distance back from the edge to produce a favorable line of fracture and subjecting the portion so cut off to heavier blows than could be effected by hand, first removing a portion of the supporting material from undeneath this hard material.

The cost of removing the cemented clay and gravel ran sometimes as high as one dollar and eleven cents per cubic yard.

Some other local questions such as long haulage, etc., have been eliminated as only embarrassing the subject under consideration.

The price of labor at the time was one and a half dollars per day for laborers, and four dollars for two carts and a driver.

A quicksand case, bearing an affinity to the subject here treated of, was under grave consideration by the Canal Board, of the State of New York some years ago, and similar questions have arisen a number of times since. It is desirable that the practice and decision of engineers should be rendered uniform, and the most effective method seems to be to place it before the Society for its consideration and action.

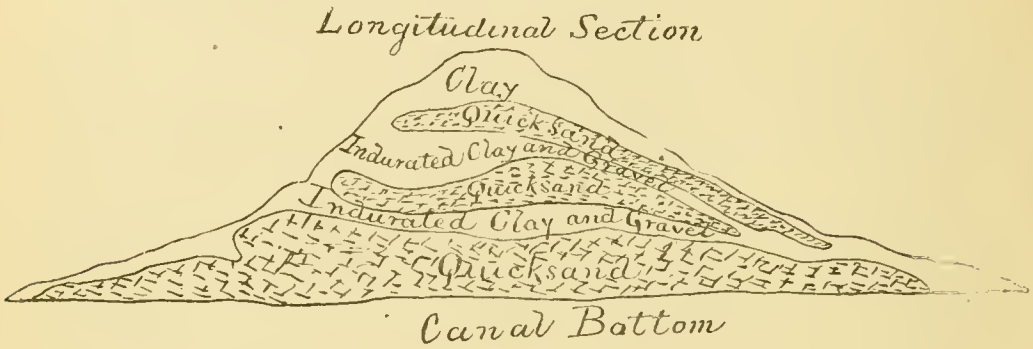
A heavy cutting on the State Works of New York, was composed of clay, sand, gravel, indurated clay and gravel, boulders and quicksand, the greater portion of which was of the latter material.

The excavations were made by teams and rail cars.

Ditches were used to a considerable extent; made and maintained at the contractors cost.

Some of the layers of quicksand, lying at greater elevations, were

more easily drained than the lower portions, and when this was effected its excavation and removal was comparatively easy.



The question in dispute was, whether it should, after drainage, be any longer considered as quicksand and paid for by the State as such, at a greater price than for common earth.

The length of the cutting was about one thousand yards, and the deepest cutting seventy-six feet.

The excavations were made from each end and at the centre.

The upper layer was well drained; the next below less so, but yet to a considerable extent; and the lower layer was much improved by ditching.

The upper layer was excavated at no greater cost than the adjacent clay; the second layer less thoroughly drained, retained its character of quicksand and cost more to excavate, and when placed in the cars it became a quivering and sticky mass before arriving at the dumping ground.

The contractors received no payment for draining the section, and all drainage by ditches or otherwise was at their own cost.

They had three classifications for earth excavation, namely, cemented clay and gravel, quicksand, "and all other excavation."

The question mentioned was so gravely entertained that it was considered necessary to obtain the opinions of several engineers, whose practice enabled them to express an opinion on the subject.

One stated that the real question was, "what was the material before a portion of it, namely, the water, was removed? If quicksand at the time of commencing the work, the payment of the quicksand price cannot be avoided."

Another said, "assuming the material to have been quicksand when the work was commenced, no methods adopted by the contractors at their

own cost, by which it was more easily excavated than was anticipated, can effect his claim to the price for quicksand. Such claim on his part is, therefore, consistent with justice as it is with usage."

Another thought that the contractor should not suffer for the results of his own sagacity, and that the cost of drainage should be considered in the same light as that for pumps or engines used for the same purpose.

Another engineer said, that much depended upon the explanations given by the engineers in charge at the time the contract was let, and upon the uniform practice on the work upon which the case occurred, and that the opinion of an engineer should be taken with much caution and due allowance for the circumstances. The result was that the contractor, after several years, settled with the state, no quicksand price being allowed on the upper strata nor upon a portion of the strata next below.

It would seem to the writer, as it may to others, that no grave question of this kind should arise in regard to the classification of this material, and that it should matter but little to the State, Company or others, who have contracted to have work done, in what manner it is performed, (so that it is done in a workmanlike and reasonably speedy manner), and if those executing it choose to first separate its component parts and remove them separately at their own cost, the object being accomplished, there are no grounds for refusing payment.

Yet that there are now and have been such questions raised, one of the proofs is the case cited.

It has been said, that as the contractors worked the cutting from the two ends much of the water would, by its own gravity, separate itself from the upper layer of the material without trouble or expense to the contractors, and that he should not claim an advantage which was the result of natural laws.

The opposition made to the payment of the quicksand price, and the trial of the case by a responsible body like the Canal Board, accustomed to the consideration and trial of many cases relating to the execution of engineering works, as well as the diverse opinions of some of the profession, renders an engineer's decision a matter of grave importance not only to the contractor and the company, but to the engineer whose fiat so often decides the case, and has led to the foregoing statements and opinions, in the hope of eliciting such expressions of the views of the

members, as may be of valuable aid in the decision of future cases, and the avoidance of injustice or costly disputes, between companies and their contractors.

Engineers will no doubt call to mind their own experience with conscientious members of Boards of Directors, whose minds become troubled when they see this formidable material reduced to the simplest conditions for excavation, and that their contractor is removing it with comparative ease, and that it is then very hard at times for the engineer to retain the directors' confidence, that his classification at an increased price is proper and right.

It need hardly be mentioned, that the expressed views of skilled engineers, such as it is hoped the discussions may bring out, would have great weight in the decision of these troublesome cases.

This paper has been entitled "Quicksand in Excavation," and it has been confined to the consideration of that branch of the general subject, namely, the proper management of this troublesome and uncertain material when it occurs in cuttings for railways, canals and other work not requiring the removal of much, if any, of it below the grade line.

But there are other descriptions of work where quicksand is encountered which may require much skill and care to safely provide for; as in the foundations of important and heavy structures; in pipe lines in cities; under massive buildings; under dams for retaining water, etc. Valuable data in regard to such cases are contained in the memoranda of most engineers, and if the interest felt in the subject by this Society is indicated, it would no doubt draw out much information covering wider ground than the writer has thought it best to occupy in a first paper on this subject.

The description of special cases, the nature of the difficulties and the methods of overcoming them, would be of great future use to the profession, more particularly as authors have greatly overlooked or omitted these important questions. Engineering text books give much information about other materials likely to occur in construction work; but this, one of the most troublesome and costly, has been strangely neglected.

Possibly it will be of service in this discussion to consider the origin of quicksands, and the peculiarity of their physical qualities upon which their characteristics depend. It may be assumed generally that the special mobility of such sands depends upon the presence of water fill-

ing the interstices of the mass. The mass yields to pressure in conformity to the laws of liquids or semi-fluids, varying with the degree of quickness. The degree of quickness depends upon, *first*, the gravity of the sand ; *second*, upon the smoothness of the surface of the particular grains of sand ; and *third*, upon the abundance of the water present with it.

Sand is a product of the action of wind or water on fragments of stone, by which, through the grinding away of the rough surfaces of the grains, they become smooth and polished. If transported under proper conditions, the grains are assorted and deposited according to size and weight, and so accumulate in large quantities, having grains with nearly uniform dimensions throughout the bed. Under some influences such beds may be percolated by currents of water saturated with lime or silica, which will be deposited on the grains of sand, roughening their surfaces, and when the process is long continued binding them into beds of sandstone. When water, free from such impurities, flows through the beds of sand they will continue as such, and when made from quartz, if the grains are very smooth surfaced, and water present, abundant enough to thoroughly fill the interstices, such sands will yield to pressure and be quicksands. In the absence of free water the friction of the grains of sand against each other will usually prevent the quickness. Obviously, the treatment will be to get rid of the water by ditching, sinking pipes and pumping it out, or cutting off its inflow.

The important question seems to be how to get water out of beds of quicksands, for when that is done, they will, in most cases, cease to be such, and will be tractable.

I venture to call attention to the possibility, in case of foundations, of injecting cement or cement-forming material into the bed of quicksand, or into seams of it when not easily controlled otherwise, converting it thus into sandstone by a quick method, very much as is done naturally by slow processes.

DISCUSSION.

William R. Hutton.—I have never had the fortune to meet in large quantities a material quite so bad as that described by Mr. McAlpine. There can be no doubt, however, that where drainage is practicable, it will enable the work to be executed in the shortest time and with least expense.

Of a somewhat similar material that has come under my notice, one or two cases will be cited. A railway track had been laid in light cutting upon a white clay full of water, although not *quaking*, and so soft that no amount of ballast would keep the track from sinking. Ditches five feet deep were dug on both sides of the road-bed, which drained it thoroughly and removed all the difficulty. In this case, as I remember, the water was carried in a seam of gravel under the clay, from which it had no outlet until reached by the drain.

At another place the cutting was deep and the material an absorbent white and yellow clay. The slopes, being drained by the excavation, maintained themselves tolerably well, although a number of small slips occurred. The road-bed, however, was very soft, and the track could not be maintained upon it. It was also very narrow, and the right of way insufficient to permit cutting back the slopes. Deep, open ditches were, therefore, impracticable, and, as an alternative, trenches were dug and filled with broken stone. This enabled the track to be laid, but the drains were liable to be choked by the earth washing down from the slopes. Tile drains would have been better.

But it is useless to cite cases of this character. Every engineer has met and overcome them, and the books are filled with them.

I have sometimes found great difficulty in making these slippery clays stand in embankments, when moved in winter or spring. After some months of dry, summer weather they seem to part with their water and become stable, as rain falling on their surface does not then penetrate deep enough to affect the mass. In one case, where a rock cutting was near, the sliding was checked by a heavy rip-rap along the lower part of the slope.

Mr. McAlpine will doubtless tell us at what slopes the cutting stood after being opened and drained; and it will be of interest to know the position of the embankment in which the material described by him was used, and the effect of water upon it after it had been thoroughly dried.

Pure clay is composed of silica, alumina and water, and the smaller the proportion of silica, the greater the quantity of water it will take up. This is the principal material forming the quicksands proper, and upon its greater or less admixture with granular matters—the sands of quartz and feldspar—depends its greater or less stability. The presence of mica, finely divided, appears to increase its tendency to move. When water in contact with it is confined by impermeable strata, it will hold large quantities. It is this material, which swells by absorption of moisture from the atmosphere, which has given so much trouble in tunnels, notably in some of the earlier English railway tunnels. Of this character also is the bad ground in the St. Gothard tunnel, where, however, according to the most recent reports, it does not swell upon contact with the atmosphere, having probably taken up all the water it can carry; but, remaining plastic or semi-fluid, exerts a pressure upon the supports "slow, constant and excessive," which is retained by arches not less than five feet thick, built of cut granite and laid in Portland cement. The clay met with in the Sutro tunnel, on the other hand, of which I have no precise description, swells very much and with a force that cannot be resisted, contracting, indeed almost closing, the tunnel, but which ceases to swell after the intruded material has been twice or thrice removed.

There are other materials, however, which bear the name of quicksands, and there is great diversity of opinion upon its character and the proper application of the term.

The river beds between the coast range of California and the sea are formed of sand which, during the dry season of summer, may be traversed anywhere, being perfectly firm, though loose and light. The water is small in quantity, and frequently stands in pools or disconnected ponds, the flow, such as there is, taking place through the sub-surface sands. But when the winter rains come, the rivers are in flood, and the sands, under the action of the current, become quicksands of the most formidable character, impassable except at the regular fords. These are *travellers'* quicksands, and I know too little of them to explain the change in their practical characteristics caused by the volume of discharge and the rapid current.

As failures are said to be more instructive than success, chiefly, I think, because they attract more attention to their details, the treatment of a case which, if not quicksand, was equally intractable, will be given.

In the construction of the Georgetown incline it became necessary to enclose a basin with an embankment and wall in the river, to be afterwards pumped out, shaped and lined. Over the rock bottom was 6 or 7 feet of silt, apparently a dark blue clay. It held water perfectly, and holes dug in it at low tide retained the sharpness of their edges after the tides and waves had passed over them. The contractor was therefore permitted, when making the preliminary dredging, to deposit some of the material upon the site of the embankment.

The bank was finished by dumping into the water clay and rock from the excavations, the clay dump being kept a short distance in advance of the rock, that the material might take its slope on both sides and the rock remain as a heavy rip-rap only on the outer slope.

After the completion of the embankment and wall, the basin was pumped out and the inside excavation commenced. At first it drained well and the work advanced, not without difficulties, but without unreasonable or unexpected trouble. But after a week's work, in an easterly rainstorm the bank settled, the high storm tide broke over the top, and the pit was flooded. The laborers, negroes, refused to work during the Christmas holidays, and everything was allowed to stand until after the New Year. When the bank was made up and the pumping resumed, it was found that a slide had taken place, which was caused by the compression and squeezing out of the dredged material in the bank. This became mingled with the more solid clay, and formed a semi-fluid mass, which would not stand at a less slope than about 1 to 5. It then became evident that the original plan of a sloped bank, kept in place by a heavy paving, could not be carried out; that a retaining wall, nearly vertical, must be built to such height as the slope at each point might require. A row of 3-inch sheeting was, therefore, driven behind a heavy stringer, which was thoroughly shored from the opposite side. As the excavation was carried on, other stringers were added below the first one, and well shored in like manner. But the instability of the material was such that, after excavating 3 or 4 feet on one side of the sheet-piling, the difference of pressure on the two sides caused a lateral movement of the lower portion of the mass, which bent the sheeting, pushing out its foot, and finally causing rotation about the lower stringer, and a further slip. A row of round piles was then driven, the better to support the sheeting, and with this the material, where not very deep, was excavated to the rock, and the slope wall or masonry built. But the

difficulty of getting in stringers and shores low enough to hold the bottom of the sheeting rendered it impracticable by this means to carry the work to the greater depths, in some places nearly 20 feet. Finally, a row of sheet-piling 12 inches in thickness was driven behind the rear line of the foundation, and shored, as before, against horizontal stringers. The foundations could then be excavated in short lengths, and the retaining walls built. The work was then completed without further difficulty, the retaining walls being carried up to meet a slope of 1 upon 2 from the top of the bank.

The question raised by Mr. McAlpine upon the classification is also of importance. Explanations given by the engineer at the letting should be in writing, and accessible to all bidders. It is a good custom at such times, when a question is asked which cannot be answered by a simple reference to specifications and plans or profiles, to write question and answer on a sheet to be attached to the profile, and retained until the settlement of the contract.

In the case referred to, an extract from the specification on the subject of quicksand would aid in forming an opinion. Supposing, however, that the contract contained a price for quicksand, but no specification concerning it, then if the material, when attacked by the contractor, was clearly quicksand, he would doutless be entitled to pay for it as such, whatever the condition to which his works, executed for the purpose, might reduce it. If before he reached it the material were drained by other works not carried out for the purpose, the question might be in doubt, and might depend upon the circumstances of the letting.

ERRATA.

Transactions, Volume X, page 238, July, 1881. Discussion by J. J. R. Croes, on Rain-Fall and the Flow of Streams. 5th line from top of page insert the figures 242, so that it will read (see p. 242).

Same number of Transactions, page 250, first line, for J. J. R. Cross, read J. J. R. Croes.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXXVII.

(Vol. X.—September, 1881.)

REPAIRS OF MASONRY.

By O. CHANUTE, Vice-President A. S. C. E.

READ AT THE 13TH ANNUAL CONVENTION OF THE SOCIETY, JUNE 15TH, 1881.

The important economical results accomplished on the Erie Railway (now the New York, Lake Erie and Western Railroad) within the last six years, by the use of béton, warrant making an exception to the general rule concerning methods which are protected by letters patent, and induce me to give an account of a material which is capable of extensive application by engineers.

Béton is simply a mortar of hydraulic cement and sand, mixed by means of patent machinery, with as little water as practicable, in pro-

portions experimentally ascertained by M. Coignet, a French engineer. When freshly made it looks like a loose, incoherent heap of damp sand, slightly coated with lime, and a more unpromising mortar can scarcely be imagined. When put into place, however, it forms a plastic mass, capable of being rammed into crevices of all masonry, of being moulded to all shapes, and made into monoliths of all kinds and sizes, from a statue or obelisk to a culvert or viaduct.

When set, it becomes a hard and imperishable stone, with a tensile strength of some 300 pounds to the square inch, and a crushing resistance of about 8 000 pounds per square inch, or about as strong as good granite, and when well made of good materials, neither time nor the elements seem to have any more effect upon it than upon the ancient Roman mortar which it resembles in its hardness and tenacity of adhesion to natural stones.

It is proposed to give an account in this paper of the uses to which bèton has been applied on the Erie Railway :

In May, 1875, the Portage viaduct, over the Genessee river, on the Erie Railway, was burned down. This viaduct, which is 850 feet long and 234 feet high above the bed of the stream, had been built of wood in 1852, and rested upon fifteen stone piers, from ten to thirty feet high. These piers were much injured externally by the fire, and when examined for the purpose of rebuilding upon them the iron viaduct which replaced the wooden one, they were found considerably shattered and shaken in consequence either of bad workmanship, the perishable nature of the stone, or the settling of the foundations.

In order to save expense, however, it was determined to use these old piers, provided they could be protected from the further disintegrating effects of the weather ; and investigation having pointed to the efficiency of béton for this purpose it was determined to try it.

A contract was accordingly made with Dr. Goodridge, President of the New York Stone Contracting Company—this being the name of the organization which controls the Béton process in this country—to repair these piers. This was done by encasing all portions exposed to the wash of water at the ordinary winter stage (which portions had been more or less shattered by frost and undermined by the action of water) with twenty-four inches of béton ; the ice breakers at the ends were also encased, and the tops of the piers were covered with a coat of béton two inches thick, to keep out infiltration, and the consequent splitting

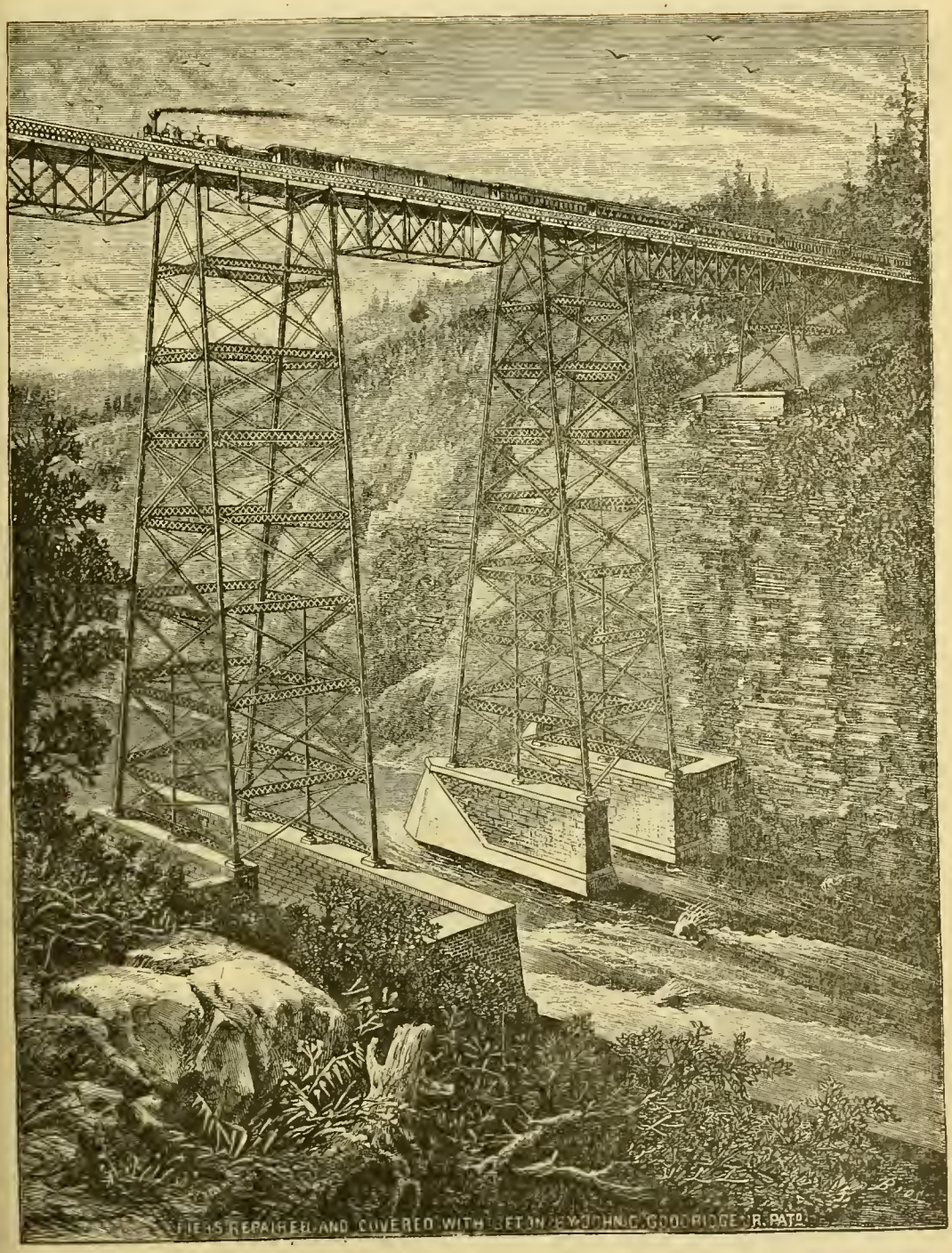


FIG. 1. PORTAGE BRIDGE.

apart of the masonry. The new pedestal blocks for the posts were also boxed in with béton to keep them firm and sound.

By examining the engraving of the bridge which is borrowed from the album of the "Stone Contracting Company" you can distinguish the portions of the piers covered with béton by their white, blank appearance. It is on top, on the shoulders of the ice breakers, and along the base, next to the water.

The amount paid to the Stone Contracting Company, for the béton work, came to about $6 000. It would have cost $40 000 to have rebuilt the piers for the new iron bridge, and thus the saving was very large. The result has been very satisfactory. The piers, to be sure, are not as good as new, but they have stood strains from the superstructure which would have shaken them all to pieces by this time if they had not been so protected.

From motives of economy less was done in 1875 than was advisable, and, as will be further stated in this paper, after an account has been given of some other uses béton has been put to, it will be employed this year in making further repairs at Portage.

The Warsaw Culvert.

Although the Erie Railway runs much of the way through a rocky country, few of the stones found along its line stand the weather. Many of the culverts, abutments and piers have therefore been eaten into by the elements, and in the course of years, not a few have been replaced by new structures.

When such culverts are under heavy embankments, their renewal involves the great expense and risk of digging them out, carrying the track upon temporary works, and rebuilding a new culvert and embankment under the trains.

In 1875 there was such a culvert near Warsaw, on the Buffalo Division, which threatened to fall into ruins. It was 146 feet long, fourteen feet in clear opening, and under an embankment sixty feet in height. The frosts had gnawed its bench walls and ring stones, until they had become an irregular mass of crumbling flakes, which came down with the slightest touch. Some of the stones were entirely gone, leaving cavities from three to six feet long, and extending back from one to three feet from the original face.

This culvert was more or less injured throughout its whole length, and hung together, apparently from the force of habit in those natural

arches, which form with time in thoroughly settled embankments. It would have cost about $36 000 to have digged it out and replaced it with a new structure, as had been done during the previous year with a similar culvert upon the Western Division; when the contractor for the Béton process offered to put a new face on the matter, for $2 200. In view of the results already accomplished at Portage, the offer was accepted.

FIG. 2. WARSAW CULVERT.

The work was done in this way: Wooden centres were erected inside of the culvert, and on these were placed lagging plank, section by section, leaving a space of about four inches between the planks and the original face of the culvert. Into this space the béton, duly mixed outside, and wheeled into the culvert, was rammed by hand until every cavity and crevice (these were previously cleaned out) were duly filled. Some of these cavities extended clear back to the earth filling, all the stone having perished. The Béton lining was also extended down the bench walls to the rock foundation of the culvert. As fast as one section was filled, the centres and lagging were put up for the next, and the work proceeded as before, from the free end.

One week after the completion of the work the centres were struck; and when removed, together with the lagging, the inside of the culvert presented a hard, smooth surface, (except the saw marks and joints in the lagging plank which had been faithfully moulded by the Béton) and the work appeared to be entirely impervious to water.

A photograph of the end of this culvert will be found reproduced in Figure 2. *A* is the original arch, and *B* the Béton lining, which has thus far stood perfectly.

It was completed just before cold weather, and some misgivings were felt by the railroad officers as to the effect of the succeeding winter. It was feared that water might percolate through the embankment and joints of the old work down to the béton, and there freeze and injure it. The culvert was therefore closely examined the next spring, but not a weather mark nor any change whatever could be discovered.

It was thought, however, that perhaps the winter of 1875 had been too mild to test the material severely, and that another season would bring different results and show some defects or weak points in this method of saving money in the repairs of masonry. No further work of this kind was therefore done in 1876, and in the spring of 1877 a new examination was made of the Warsaw Culvert to detect any possible injury. None whatever was found, but it was then, and it is now, after a winter as severe as heart could wish, as perfect as when originally built.

The Clifton Culvert.

In the spring of 1877 it was reported that a culvert at Clifton, 12 miles from Jersey City, needed to be rebuilt. It had originally been constructed of red sandstone from quarries in the vicinity, and was not only dilapidated and peeled by the weather, but it had settled upon its foundation, so that it was in a very dislocated and disjointed condition. Its wing walls had parted from its main walls, the parapet had been pushed out by the thrust of the earth, so that it partly overhung the arch, and, singular to relate, it being under a shallow bank, the vibrations of the trains acting upon the earth that pressed against the culvert, had actually lengthened it, so that its barrel was two feet longer than originally built. We know this to be a fact, for we found the original record plan, we measured the culvert carefully, and found enough openings in the joints fully to make up the two feet it had lengthened.

It would have cost $6 000 to have rebuilt this culvert, but a contract was made to repair it for $600. This was done by lining it with an inside ring of béton, 4 inches thick, rammed into all the crevices and joints, and building béton buttresses at the ends, to prevent any further

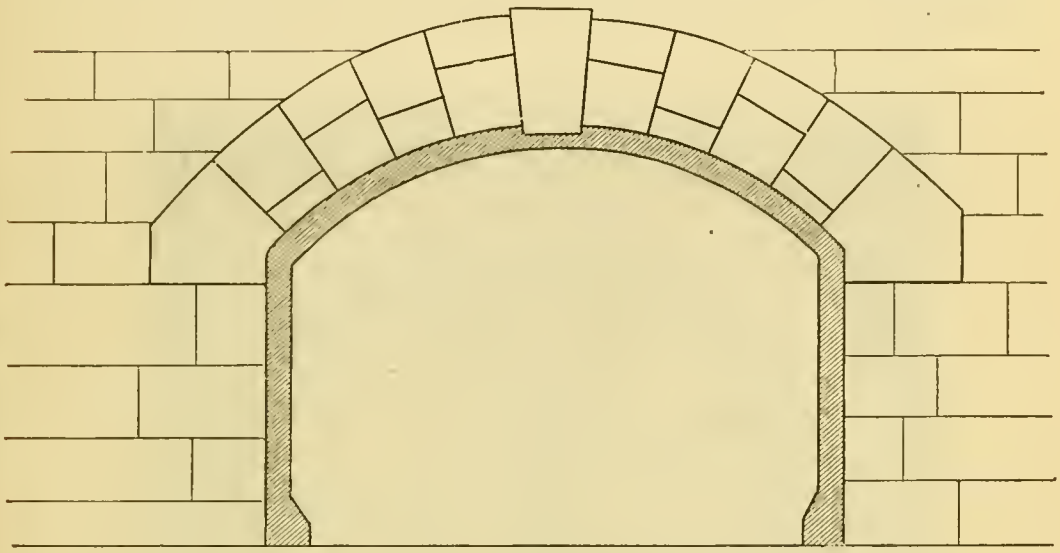


FIG. 3. CLIFTON CULVERT.

creeping away of the structure from under the trains. The success has been complete, and the culvert is now as good as new. A geometrical end view of it is given in Figure 3.

Bergen Tunnel.

In the fall of the same year it became necessary to make some repairs to the Bergen Tunnel at Jersey City. This tunnel is 4 316 feet long, and driven through trap rock. This, although very hard and unaffected by the weather, is full of seams and faults, and being entirely unstratified, it comes down in blocks of isolated stones, which set dangerous traps for the trains. Some portions had been arched from time to time, but this had been done with brick, and in the course of years, alternate freezing and thawing had peeled off the face from the bricks, generally in flakes about one inch thick, until in some places the arching had been eaten into for a depth of 8 inches.

It was decided to arch over an additional section 130 feet long, where the naked trap rock was badly shattered, and to reline with a thin coating of béton another section 30 feet long, in which the bricks had been most injured.

This was done by erecting iron centres, so arranged as to clear the trains, placing on the centres wooden lagging plank, and ramming the space between them and the face of the rock or brick, full of béton, the latter being mixed on cars in the tunnel.

This work was all done at night, in order to have the least annoyance from trains, of which some 200 pass through every 24 hours.

FIG. 4. BERGEN TUNNEL.

Figure 4 represents a section of that portion of the tunnel in which the béton was applied to the rock. When an infiltration of water was struck, in order to drain it and to prevent the formation of the stalactites of ice which hang down (and fall down) every winter from the rock, drain tubes were left in the beton by inserting hollow blocks made at the factory.

The work was successfully accomplished, and has stood perfectly ever since.

Buffalo Division Culverts.

Thoroughly convinced by these successes, a further contract was made in 1878 to repair, by the same means, a number of culverts on the Buffalo Division, which were getting into the same condition as the one at Warsaw, which I have described.

The following is a list of them :

No. of Culvert.	Length in Feet.	Span in Feet.	Crown of Arch to Foundation. Feet.	Height of Embankment. Base of Rail to bed of Stream. Feet.
80	147	10	17	87
3	141	10	12½	62
112	118	6	7	72
100	100½	6	9	39
4	112	10	13	63
77	52	6	10	28
101	46½	5	8	24
104	52	5	8	24
105	46	5	8	24
49	65	6	9	33
51	87	5	8	32
54	71	6	9	34
73	117	6	8	48

These 13 culverts, which had been built in 1851–2, had been nursed for some years, and exhibited all the ills to which masonry is subject in its old age. The stones were disintegrated, portions had caved in, the foundations were undermined, the bench walls were broken-backed, the arches were distorted, and the ends and parapet walls were thrust out. These were repaired with appropriate doses of béton.

Figures. 5 and 6 show the end of culvert No. 101, and Figures 7 and 8 the end of culvert No. 4, before and after taking Dr. Goodridge's "Bétou Specific."

I regret that I cannot show you also photographs of the interior of these culverts, to exhibit their other defects. These were much worse than those shown.

FIG. 5. CULVERT 101. BROKEN.

FIG. 6. CULVERT 101. REPAIRED.

FIG. 7. CULVERT 4. BROKEN.

FIG. 8. CULVERT 4. REPAIRED.

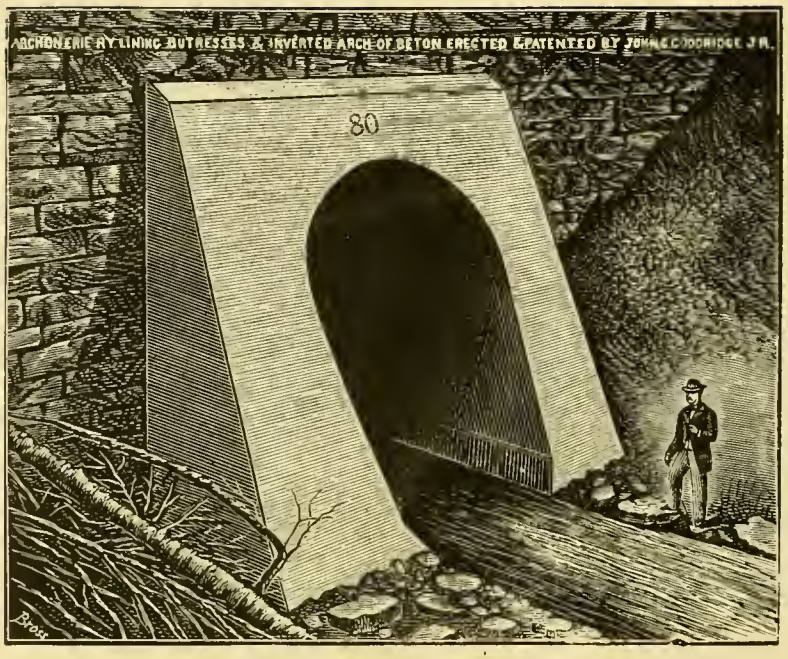


FIG. 9. CULVERT 80. REPAIRED.

Figure 9 shows how Béton buttresses were applied to culvert No. 80, which is built on a slant on a sloping bed of shale, which disintegrates with the weather. An invert, partly shown in the cut, was put in to prevent further injury.

Figure 10 shows a similar invert in culvert No. 112. The middle of this had caved in, and the arch was distorted. This culvert was 118 feet long.

Figure 11 shows the new form given to culvert 105, in which the ends were down, and the interior much injured.

In all cases in repairing these culverts, all the loose mortar was picked out of the joints, the loose flakes of stone were knocked off, and the béton was rammed into all the holes and interstices.

We estimate that it would have cost to dig out and trestle these culverts, some of them being, as will be seen by the table, under embankments from 60 to 80 feet deep, and to have rebuilt them with new masonry, at say $10 a yard, the sum of about $80 000. We paid the contractor for repairing them $15 112 45, and we estimate that the labor of our carpenters, making and erecting centres, the free transportation of men and materials over the road, &c., &c., may have amounted to $5 000 more, so that the aggregate cost to the railroad was about $20 000.

The economy of the process was, therefore, marked and monotonous. All the culverts have stood perfectly ever since.

FIG. 10. CULVERT 112. REPAIRED.

FIG. 11. CULVERT 105. REPAIRED.

West Paterson Bridge.

In the spring of 1880, the two piers, under the double-track iron bridge over the Passaic river, at West Paterson, were reported as cracking open and falling asunder. They were founded upon cribs, resting on the sandy bottom of the river, and the settling of the cribs, together with the jarring of the trains, was shaking the piers to pieces. It would have cost $12 000, and have involved some risk, to have rebuilt them under the bridge. After careful consideration and discussion, it was decided to envelope them entirely in a shell of béton from 4 to 12 inches thick. For this purpose wooden frames, planked inside, were erected at a suitable distance off, all around the pier, and the space between the planks and the stones was rammed full of béton. A coat 4 inches thick was also put on top, the whole enclosing six iron rods, three on a side, which had been temporarily put around the pier, to keep it from tumbling apart while its permanent repair was under discussion.

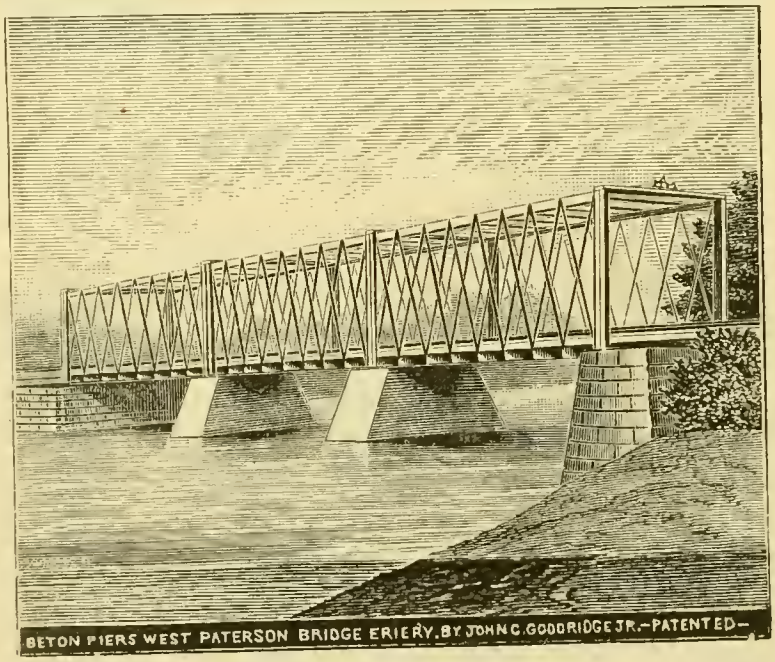


FIG. 12 WEST PATERSON BRIDGE.

The cost has been $6 000, and it is confidently believed that the piers are now good for many years; for the béton being an average of 12 inches thick on the sides, and 4 inches on top, and of a tensile strength of say 300 pounds per square inch, it would require an internal stress in the pier of

One side,	12 ft. × 12 in. × 12 in. × 300 =	518 400	pounds.
Other side,	12 ft. × 12 in. × 12 in. × 300 =	518 400	"
Top.....	5 ft. × 12 in. × 4 in. × 300 =	72 000	"
		1 108 800	"

to burst its shell asunder, while the 6 iron bolts 1⅛ inches diameter, are only good for 300,000 pounds.

These piers are shown in Figure 12.

Dam at Portage.

In the fall of the same year in became necessary to make further repairs at Portage. The stones in one of the piers which had been injured by the fire were found to be flaking off dangerously near to one of the pedestal blocks, which carry the posts. This was easily repaired and further disintegration prevented by a buttress of béton over the injured spot.

Another pier was found more seriously affected. It had been built on top of a loose mass of rubble stone about 20 feet thick, thrown out when the Genessee canal was excavated, and, although strong enough to carry the wooden trestle, with its many posts, proved insufficient to carry the concentrated weight on the two iron posts which constitute the iron piers. Their weight had broken the back of the stone pier and forced down the outer ends some two inches into the rubble beneath. There was no telling where the injury would stop, and repairs were urgent. As it was late in the season when this was discovered, temporary repairs only were attempted. These were made by throwing out béton buttresses, beyond the ends of the pier, thoroughly bonded with it, and thus increasing the bearing area upon the loose rubble to about double the amount it had before. This has stopped further settling for the present, but to be entirely safe, we deem it necessary to extend the foundations under the iron posts either down into or entirely through the loose rubble, which is on a sloping bank of rock.

This we propose to do by drifting in narrow galleries through the loose rubble under the pier, and filling them with béton, which, when thoroughly set into stone, we propose to use as the sides and roof of other galleries, to be likewise drifted in and filled with béton, until we have a solid mass under the pier to a suitable depth.

I will tell you next year how we have succeeded.

We also propose to administer béton to the Genessee river. This has worn its way to a depth, varying from 200 to 600 feet, through the Portage group of clay shales, which have a bad notoriety for their disintegration under the action of the weather.

When the Portage bridge was first built, a waterfall 60 feet high had its crest 240 feet down stream from the bridge. It wore back, first in the shape of a horseshoe, and then all on one side, so that now, the nearest point in the top of the cascade is only 119 feet from one of the piers, and it is wearing back at the rate of about 15 feet a year. The chief trouble arises from the shaly, rocky bed of the river, which cleaves into blocks, shells off and is swept down the waterfall by the floods. Operations were begun last fall by running a béton dam 210 feet long and 3 feet high, which deflects all the water, at ordinary stages, from the portion where the rock has been wearing away fastest, but is submerged in floods; and will be followed up this year by filling in with rubble masonry a cavity in the rock, where the water is boring a dangerous channel nearest to the pier, and putting an apron or floor of béton over the whole bed of the stream where there is fear of its wearing back.

Blauveltville Culvert.

The preliminary work at Portage last fall occupied so long, that winter was upon us before we could repair a culvert of 16 feet span at

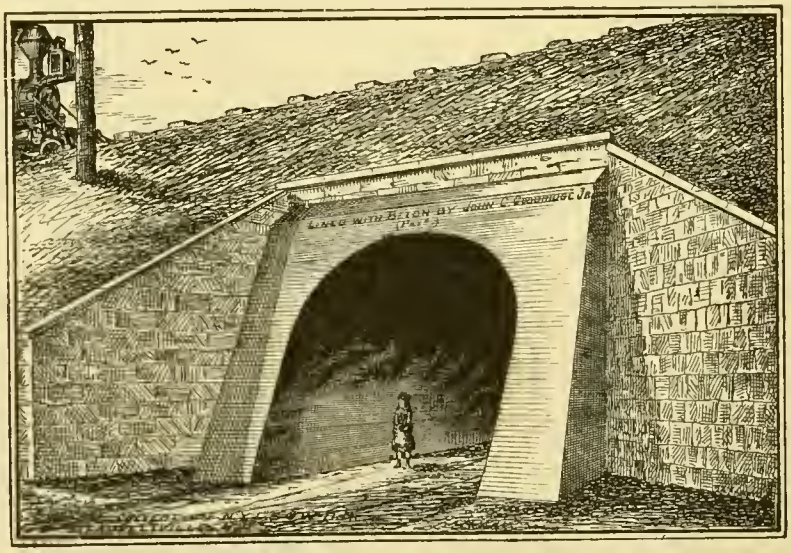


FIG. 13. BLAUVELTVILLE ARCH.

Blauveltville on the Piermont Branch, which carries a wagon-road under our track. However, in December the travel was turned over to an adjoining road, both ends of the culvert were boarded up, a couple of stoves were put in it, the pipes run out through the ends, and the béton men, provisioned with the necessary sand and cement, as food for their machine, went into winter quarters. They emerged this spring, leaving a new culvert lining behind them.

The end is shown on Figure 13.

Cost of the Work.

In doing this work, different prices have been paid, according to the difficulties of the various locations; varying from 60 cents to $1.00 per cubic foot, or from $16.20 to $27.00 per cubic yard. No new structures have been built entirely of béton, because, although they could be made considerably lighter in consequence of the greater strength of the mass, thus forming one single monolith, we have not deemed such structures more economical than masonry, where good stone can be procured at about $10.00 a cubic yard in the work. Where, however, stone is scarce and sand plenty, the béton would be the cheapest.

The cost would be reduced, if it were found possible successfully to use some of our American cements. A Portland cement, made at Boulogne, in France, has been used exclusively on the works above described, and the contractor says that his attempts to make good béton with American cements have resulted in failures. There have been failures also in France; some of the sewers of Paris, lined with some cheap stuff, are said to have peeled off, and the viaduct of La Vanne, which was wholly built of béton, is said to have cracked and flaked off to a dangerous extent. The proportions used for this structure, I understand to have been

20 parts of sand,
4 " lime,
1 " cement.

So that this is a formula clearly not to be used. In fact, I can give you no formula, as the proportions are said to vary with the fineness of the sand, and the character of the béton which is required.

We have preferred to have all our work done by contract instead of attempting it ourselves, in order to make sure that the proportions and workmanship should be controlled by experts. The results have been

entirely satisfactory. Large sums of money have been saved, not a single failure has occurred, and the repaired works seem likely to endure as long as if originally built of sound stones.

It is believed that the methods which have been described, are capable of still further adaptation and extension. Existing structures, the rebuilding of which would seriously interfere with the continued use of a road, canal or edifice, can be repaired with béton, as has been shown, without interference with the traffic, and at a cost of from ten to twenty per cent. of the expense of a new work. This can also be done very rapidly, six thousand cubic feet of béton, or over two hundred cubic yards, having, in some instances, been put in in a single day, so that engineers who may adopt this method of repairing masonry may be certain of saving both time and money.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CCXXVIII.

(Vol. X.—September, 1881.)

STRENGTH AND DUCTILITY OF THE COPPER-TIN-ZINC ALLOYS.

By ROBERT H. THURSTON, Member of the Society.

PRESENTED AT THE 13TH ANNUAL CONVENTION, JUNE 17TH, 1881.

In a paper read before the American Society of Civil Engineers a few months since,* the writer gave an account of a method of research which led to the approximate determination of the composition of the strongest possible triple alloy of copper-tin-zinc, and described the properties of alloys made with more or less accuracy and care by the formula of com-

* "THE STRONGEST OF THE BRONZES." Trans. Am. Soc. C. E. No. CCXIV.; Vol. X.; Jan., 1881.

position so obtained. In order to exhibit the relation of such metals to the other triple alloys, some of which were already well known compositions, a sketch was given of the relief model used in the identification of the strongest possible metal obtainable by mixture of the three constituents, and a map exhibiting lines of equal tenacity as derived by admeasurements of this model was also introduced as presenting the tenacity of the alloys with greater exactness. This map is here reproduced with some modifications (Fig. 1), which are demanded in further study of the characteristics of these alloys. It was remarked in the earlier paper :

"These alloys were purposely made precisely as the brass-founder is accustomed to make them, without other precautions than those observed by every good founder, and without using any of the deoxidizing fluxes—as phosphorus—that would have been experimented with later. The intention was to make this first survey of the field rapidly, inexpensively, and in such a manner as to give a good idea of the best way to pursue the later and much more exact research, while giving the founder a good idea of the nature of the metals that he turns out in every day work.

"The data obtained were consequently exceedingly variable, and the results of this work indicated as one, and not the least valuable, of deductions from it that the same alloy, and especially where the proportion of copper is great, may give very different figures, when tested, according as it is more or less affected by the many circumstances that influence the value of all brass-foundry products.

"Some of the variations in the model are probably due to such accidental circumstances, and quality shown by any individual alloy is representative of a mean which the writer was often compelled to deduce from observations which were quite discrepant. But allowing for all such minor variations, it is evident at a glance that the alloys of maximum strength are grouped, as shown in Figures 3 and 4, about a point not far from copper = 55, zinc = 43, tin = 2. This point is encircled in the map, Figure 3, by the line marked 65 000 pounds per square inch (4 570 kilogs. per sq. cm.) tenacity, and is represented on the model by the peak of the mountain seen at the farthest side—the copper-zinc side as drawn.

"This is obviously the strongest of all bronzes, and an alloy of this composition, if exactly proportioned, well melted, perfectly fluxed, and so

poured as to produce sound and pure metallic alloy, with such prompt cooling as shall prevent liquidation, is the strongest bronze that man can make."

This alloy and the "Tobin alloy"—copper, 58.22 ; tin, 2.30 ; zinc, 39.48—were described as good working metals, having toughness and some ductility as well as great strength, and the latter as being capable of great improvement by skillful working either hot or cold, and thus of attaining a tenacity of over 100 000 pounds per square inch (7 311 kilogs. per sq. cm.). Following the inequalities exhibited by the map, the writer called attention to the fact that a line of maximum elevation crosses the field from about : copper, 50 ; zinc, 50 ; to copper, 85, tin, 15, is included in a band bounded by the formulas : $M = Z + 4\,t = 50$, and $M = Z + 3\,t = 55$, in which Z is the percentage of zinc present in any triple alloy of that series, and T is the percentage of tin. It was stated that along this maximum line the tenacities of the alloys should be at least $T_m = 40\,000 + 500z$ in pounds on the square inch, or $T^1{}_m = 2\,812 + 35.15z$ in kilograms on the square centimeter. Thus taking the last line which contains the strongest but least ductile compositions, we find the following tenacities :

The alloy $z = 1$, $t = 18$ will also contain copper $= 100 - 19 = 81$ and this alloy cu. 81, zn. 1, sn. 18 should have a tenacity of at least

$$T_m = 40\,000 + (500 \times 1) = 40\,500 \text{ lbs. per sq. in.}$$
$$T^1{}_m = 2\,812 + (35\,15 \times 1) = 2\,847 \text{ kgs. per sq. cm.}$$

The alloy : cu. 60 ; zn. 5 ; sn. 16 ; should have at least the strength .

$$T_m = 40\,000 + (500 \times 5) = 42\,500 \text{ lbs. per sq. in.}$$
$$T^1{}_m = 2\,812 + (35.15 \times 5) = 2\,988 \text{ kgs. per sq. cm.}$$

while the alloy z, 50 ; sn, 2 ; cu, 48 ; should give, as a minimum per specification :

$$T_m = 40\,000 + (500 \times 50) = 65\,000 \text{ lbs. per sq. in.}$$
$$T^1{}_m = 2\,812 + (35.15 \times 50) = 4\,570 \text{ kgs. per sq. cm.}$$

"These are rough working formulas that, while often departed from in fact, and while purely empirical, may prove of real value in framing specifications. The formula for the value of T_m fails with alloys containing less than 1 *per cent. tin* as the strength then rapidly falls to $t = 0$."

The writer does not recommend these alloys of maximum tenacity for all purposes of construction, as many of them, especially those near the tin side, are too deficient in ductility and resilience to be safely used where likely to be exposed to severe shock. Where the composition is that of brass, rather than bronze, this line of alloys exhibits more toughness. The alloys—copper, 55 ; tin, 2 ; zinc, 43 ; and copper, 55, tin, 0.5 ;* zinc, 44.5—were quite excellent in this particular. Tin reduces ductility more rapidly than does zinc. Alloys on the copper side of $z + 4t = 40$ are all tough metals. The copper tin alloys or bronzes, as was stated, should have a tenacity of at least : $T_t = 30\,000 + 1\,000t$ where containing not more than about 15 per cent. tin, or in metric measure, $T^1{}_t = 2\,109 + 70.3\,t$, while the brasses or copper-zinc alloys up to 50 per cent. zinc should have a strength, in British and metric units respectively, of $T_z = 30\,000 + 500z$ and $T^1{}_z = 2\,109 + 35.15z$. Thus gun bronze can be given about $30\,000 + (1\,000 \times 10) = 40\,000$ lbs. per square inch if well made. In metric measures, $2\,109 + 703 = 2\,812$ kilogs. per sq. cm. Copper, 70 ; zinc, 30, should have a tenacity of $30\,000 + (500 \times 30) = 45\,000$ lbs. on the square inch, or $2\,109 + (35.15 \times 30) = 3\,165$ kilogs. per square centimeter. Comparing the last two formulas for tenacity, it is seen that they may be combined giving equations covering the whole field of copper-tin-zinc alloys useful to the engineer, thus :

$$T_{zt} = 30\,000 + 1\,000\,t + 500z.$$
$$T^1{}_{zt} = 2\,109 + 70.3\,t + 35.15z.$$

But it must be understood that this approximate statement of tenacities is a minimum for well made alloys, and is also applicable only to those containing a larger percentage of copper than to those which lie along the maximum line ; the alloys to which they apply are, however, the best alloys for general use. Like all such formulations, they must be taken with reserve, and as only representing the cases from the study of which they were derived. For all ordinary purposes of the engineer they may be used without hesitation. Thus we get, for alloys in which $z + 4\,t < 40$, the following tenacities, representing the minimum that should be accepted ; these figures may be greatly exceeded :

* Not 2.5, as printed in the earlier paper.

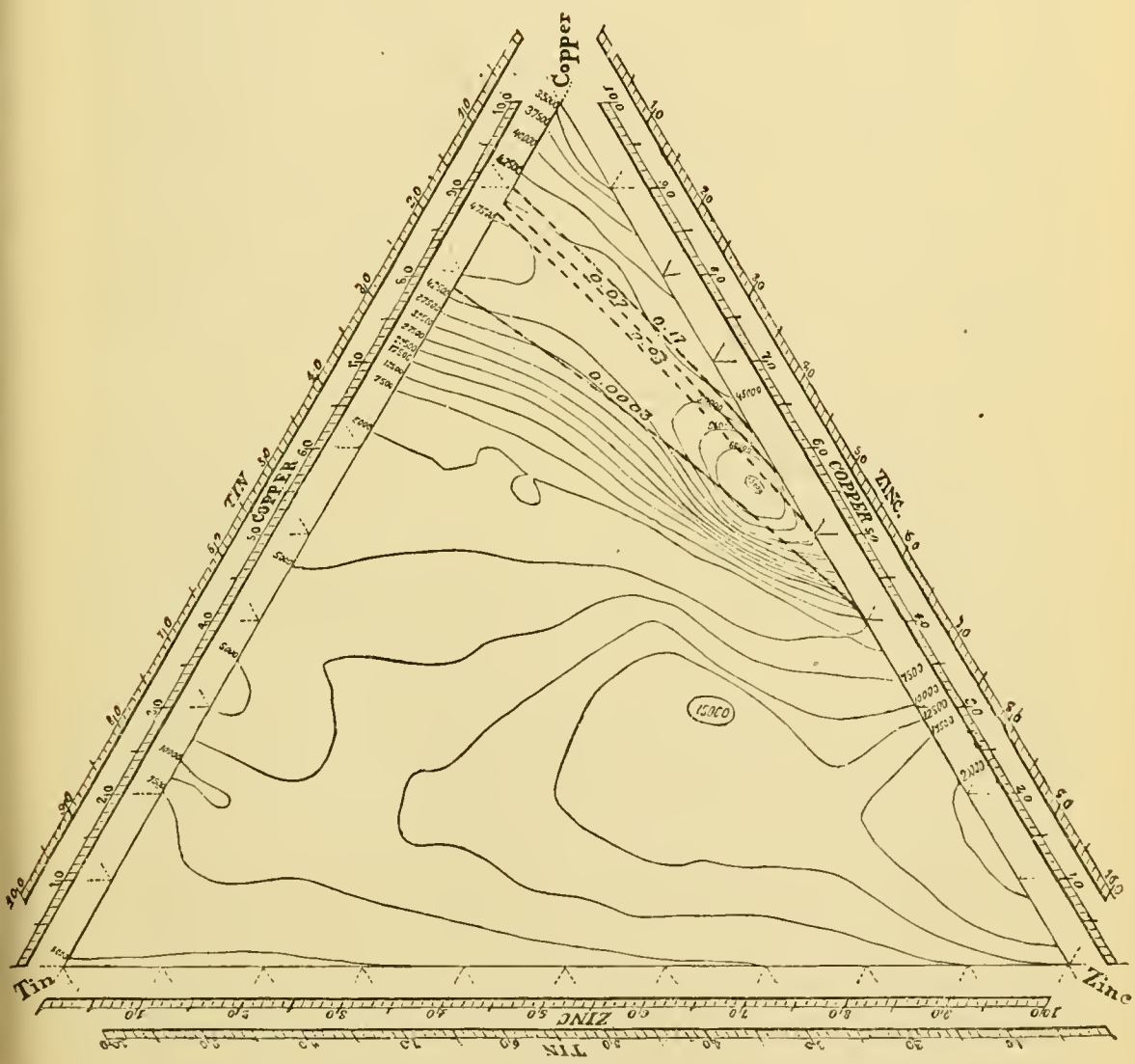
Copper
Tin
Zinc
TIN
COPPER
ZINC
COPPER
ZINC
TIN
0.07
0.17
0.03
0.0003
15000

FIG. 1.

Alloy.			Tenacity—Probable Minimum.	
Cu.	Zn.	Sn.	Lbs. per sq. in.	Kgs. per sq. cm.
100	0	0	30 000	2 109
95	5	0	32 500	2 285
90	10	0	35 000	2 460
85	15	0	37 500	2 636
90	0	10	40 000	2 812
95	0	5	35 000	2 460
97½	0	2½	32 500	2 285
90	5	5	37 500	2 636
85	10	5	40 000	2 812
75	20	5	45 000	3 163
68	30	2	47 000	3 304
64	35	1	48 500	3 410
60	40	0	50 000	3 515

The ductility of these alloys is a subject of quite as much interest to the engineer as their strength ; and in this quality the triple alloys are as variable as in every other. Referring again to the map, Figure 1, it is seen that a closely grouped set of slightly curved and slowly converging lines cross it from about tin $=25$ to zinc $=55$, the mean line having an equation, nearly $2.2t+z=55$. Along this line the alloys have an immense tenacity as exhibited by the fact that some of them, if not nearly all, are too hard to be cut by steel tools, and in shaping them only grinding tools—either the emery wheel or the grindstone—could be used, and even then with most unsatisfactory results. Yet such was the brittleness of these metals that no reliable test of their strength could be obtained. Even the slow and cautious handling possible in the autographic machine was quite inadequate to the production of regular and satisfactory determinations. The strain diagrams obtained were perfectly straight, and nearly vertical lines terminating suddenly when the piece snapped without the slightest indication of approach to an elastic limit. They were apparently perfectly elastic up to the point of fracture, but were so nearly destitute of resilience that no use can probably be made of them. Their brittleness was such that they would often break in the mould by their own contraction in cooling, although cast in a straight bar one inch (2.5 c. m.) thick and less than 30 inches (75 c. m.) long. In some cases they were cracked by the heat of the hand, and in several instances were

broken at the end by the jar transmitted from a light blow struck at the other end.*

The border lines of this valueless territory is shown on the map by a slightly curved dotted line to which a line having the equation $2.5t + z = 55$ is nearly tangent. The alloys lying along this line have nearly equal ductility, extending according to the measurements obtained by the autographic machine, about .03 of one per cent.

Above this line is seen another having nearly the equation $4t + z = 50$, which last line is that of equal ductility for alloys exhibiting extensions on the strain diagram of 3 per cent. Still nearer the "pure copper corner" fairly representing alloys containing about $3\frac{3}{4}t + z = 48$, and along which the extensions, as per strain diagrams were 7.3 per cent., and another such line extending from the standard gun-metal compositions on the one side to the tough Muntz metal on the other—cu. 90 ; sn. 10 ; to cu. 55 ; zn. 45 ;—of which the equation is nearly $4.5t + z = 45$, represents and identifies alloys averaging as cast during this initial research, an extension of 17 per cent. These lines are best seen on the sheet of extensions, Fig. 2. All alloys lying above the line taken here as a boundary line give figures for tenacity that are usually considered good ; they all exceed 30 000 pounds per square inch (2 109 kilogs. per sq. cm.).

It is seen that the addition of tin and of zinc to cast copper increases tenacity at least up to a limit marked by the line $3t + z = 55$, and that the influence of tin is nearly twice as great as that of zinc, while the limit of useful effect is not reached in the latter case until the amount added becomes very much greater than with the former class—the copper-tin alloys.

Brasses can be obtained which are stronger than any bronzes, and the ductility of the working compositions of the former class generally greatly exceeds that of the latter.

Triple alloys may be made containing about $4t + z = 50$, which exceed in strength any of the double alloys and compositions approaching copper, 55 ; tin, 2 ; zinc, 43 ; as the maximum of maximums, may be made, which are of extraordinary valne for purposes demanding great strength, combined with the peculiar advantages offered by brass or bronze. The addition of one-half per cent. tin to Muntz metal confers vastly increased strength. So sensitive is zinc to the presence of tin that M. Bischof

* Report of United States Board,

states that he can detect the addition of one part of tin in ten millions of pure zinc.

The range of useful introduction of tin is very much more restricted than with zinc ; alloys containing 12 to 15 per cent. tin are so hard and brittle as to but rarely find application in the arts, while brass, containing 40 per cent. zinc, is about the toughest and most generally useful of all the copper-zinc "mixtures." The moduli of elasticity of these alloys are remarkably uniform, more than one-half of all those here described, ranging closely up to fourteen millions, or one-half that of well made steel-wire, such as is used in the New York and Brooklyn Bridge. The moduli gradually and slowly increase from the beginning of the test to the elastic limit.

The fracture of these alloys is always illustrative of their special characteristics. Those broken by tortion in the autographic testing machine were, if brittle, more or less conoidal at one side of the break ; ductile alloys yield in similar circumstances by shearing in a plane at right angles to the axis of the test piece ; the former resemble cast iron and the latter have the fracture of wrought iron. Every shade of gradation in this respect is exhibited by an observable modification of the surface of fracture varying from that characteristic of extreme rigidity and brittleness, through an interesting variety of intermediate and compound forms to that seen in fracture of the most ductile metals.

Notwithstanding the fact that the demise of the United States Board left this investigation in a sadly incomplete state, it will probably become evident to those who may obtain the report that at least a beginning has been made and the field fairly reconnoitred, leaving to some future investigator a prospect of immediate valuable recompense for such additionable labor as he may be able to expend in a detailed reconnoissance or an extended survey. While studying the figures here given, and especially those reported by the United States Board, it must not be forgotten that the tenacities and even the ductilities given are far within the best attainable figures where they relate to the most valuable working bronzes and brasses. These figures represent the result of ordinary, every day founders' work, and metals rich in copper made, as were these, with no greater precaution against oxidation and liquation than is usual in brass foundries, may be vastly improved by the special treatment suggested in the preceding paper—by using pure ingot metals, fluxing carefully, as with phosphorous or manganese, casting in chills, rapid

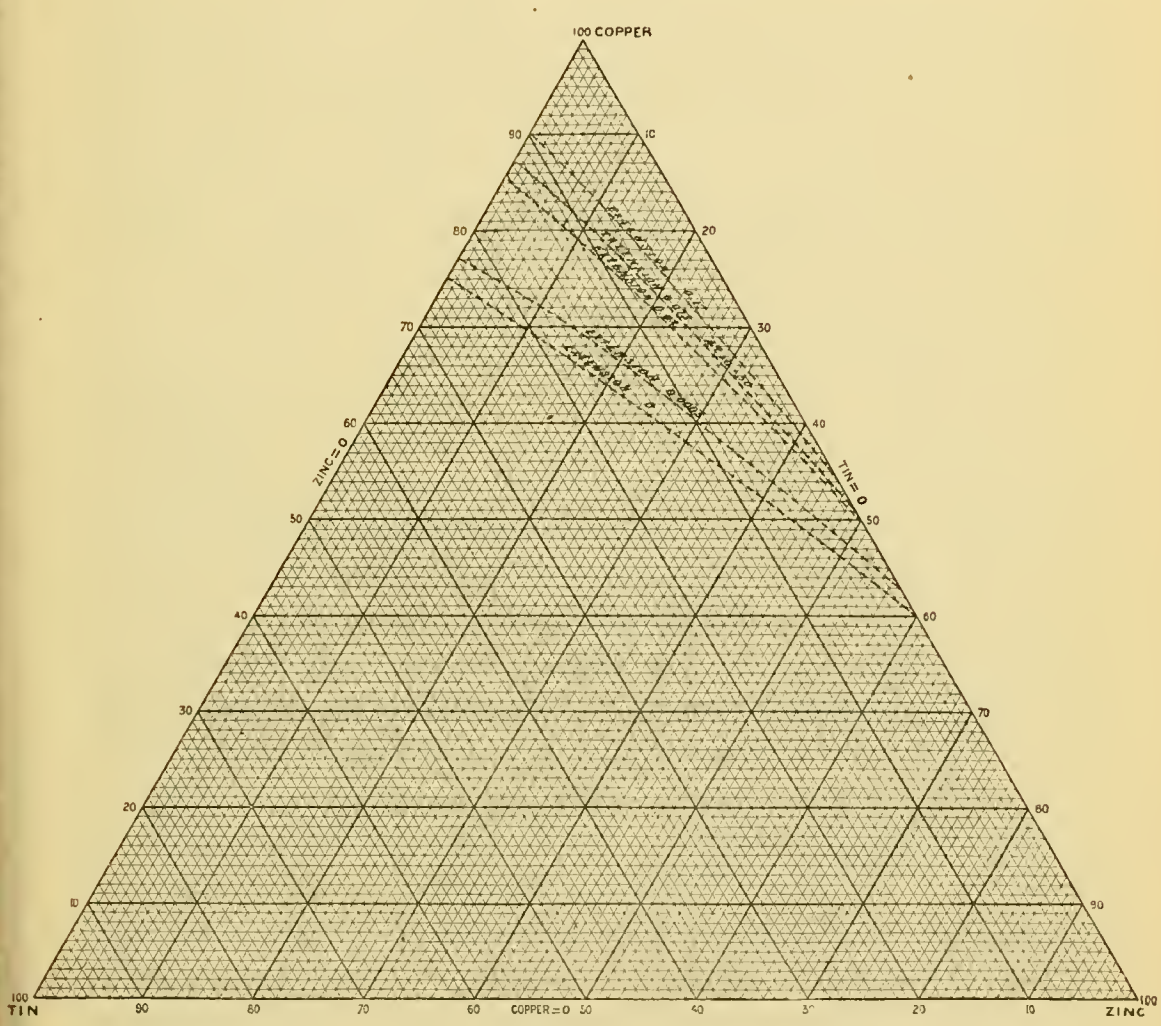
100 COPPER
90
10
80
20
70
30
60
40
50
50
40
60
30
70
20
80
10
90
100
TIN
90
80
70
60
COPPER = 0
50
40
30
20
10
ZINC
100
ZINC = 0
TIN = 0

FIG. 2.

cooling, and finally rolling or otherwise compressing either hot or cold.

Unannealed copper wire is reported by Baudrimont* as having a tenacity of about 45 000 pounds per square inch (3 163 kilogs. per sq. c. m.), and Kirkaldy reports 28.2 tons per square inch (63 168 pounds per square inch; 4 440 kilogs. per square c. m.), the wires having diameters of 0.0177 and 0.064. inches (0.044 and 0.165 c. m.) respectively.

It can hardly be doubted that a way may yet be found to secure equal purity, homogeneousness and density in cast copper, and such metal should then possess equal tenacity and toughness with rolled metal. Gun-bronze, which ordinarily has a tenacity of about 35 000 pounds per square inch (2 460 kilogs. per sq. cm.) has been made at the Washington Navy Yard, by skillful mixture, melting and pouring, to attain a tenacity of above 60 000 pounds (4 218 kilogs.).

The effect of thorough fluxing with deoxidizing substances is so important that no founder can safely neglect it.

Bronzes fluxed with phosphorus, arsenic, and manganese have been given fifty per cent. higher tenacity than the ordinary unfluxed alloy, and the addition of a little iron, as in the so-called "sterro-metal" of the Baron de Rosthorn, and in Parson's "Manganese Bronze," has still further strengthened the copper-tin-zinc alloys.

Attention has been called in the preceding paper to the value of cold rolling, and other mechanical treatment of the "maximum alloys," examined by the writer, and one case was cited in which the tenacity was increased from 66 500 pounds per inch (4 575 kilogs. per sq. cm.) by rolling hot to 79 000 pounds (5 553 kilogs.), and by cold rolling to 104 000 pounds (7 311 kilogs.). Dr. Anderson, the Superintendent of Machinery of the British War Department, when associated with the writer at Vienna, 1873, referred to experiments at Woolwich, showing an increase of strength of sterro-metal by forging to the extent of 25 per cent., and by drawing cold of 40 per cent. Brass, containing copper, 62 to70; zinc, 38 to 30, attains a strength in the wire mill of 90 000 pounds per square inch, and sometimes of 100 000 (6 327 to 7 030 kilogs. per sq. cm.), and the time will come, we may hope, and fairly expect, when these alloys may be made equally tenacious tn the casting. The writer has no doubt that the methods indicated by him as those best adapted to secure dense, strong and tough

* Annales de Chimie, 1850.

metal will yet be found capable of yielding alloys of more than double the strength shown here to be fairly representative of what is now ordinary brass founder's work. It should be possible to secure copper-tin-zinc alloys having tenacities represented by :

$$T_{mm} = 60\,000 + 1\,000t + 500z,$$
$$T^1_{mm} = 4\,218 + 70.3t + 35.15z,$$

throughout that area on the map representing the more useful alloys, say from copper, 100 ; to $4t + z = 50$.

Manufacturers of special bronzes are already approaching this degree of excellence. The appended tables illustrate the method of investigation adopted in studying the triple alloys, and exhibit the behavior under test of the sample of "Gun Bronze, No. 1 252," of which autographic strain diagrams were given in fac-simile in the preceding paper on "The Strongest of Bronzes." This bar was made to order for the writer to determine the value of an organic material proposed as a flux ; it had no special value, however, and the record is here given in illustration only.

No. 585 was a sample of brass in which 20 per cent. zinc takes the place of 10 per cent. tin in bar No. 1 252. This piece had very nearly the same tenacity, double the ductility, a slightly lower modulus of elasticity, and far less transverse strength—probably in consequence of less hardness. Adding zinc until the proportion becomes 37.5 per cent., as in No. 609, the tenacity rises to 48 760 pounds per square inch (3 428 kilogs. per sq. cm.), the modulus of elasticity is increased to fifteen millions, and the transverse strength is doubled.

No. 856 is an alloy of very nearly the same composition, to which 23 per cent. tin has been added. It is seen that this change has produced an enormous increase of strength, bringing the tenacity up to 67 600 pounds per square inch (4 752 kilogs. per sq. cm.), and while decreasing the modulus of elasticity has greatly increased the transverse strength. This bar was referred to in the preceding paper, and the records of its test are here also appended as exhibiting the behavior of this alloy during the progress of the tests. The extensions given are measured in a length of five inches ; they are, therefore, to be multiplied by 20 to obtain the percentage of extension. This bar is very strong, but deficient in ductility.

The transverse test exhibits these characteristics with equal distinctness. The load carried was nearly a ton and a half, and the deflection

but 2 inches (5 cm.); the modulus of elasticity slowly but steadily decreased from the start. Note (*a*) calls attention to a singular phenomenon more than once noticed, of an increased effort to decrease flexure after a short interval of rest under light load, having received set under heavier stress. The remainder of the record illustrates the usual gradual increase of set under heavy loads. Somewhat similar behavior was noticed in the transverse test of No. 1 001, an alloy of which the strain diagrams from the autographic machine were given in the paper on the strongest of the bronzes. The note appended to the record calls attention to this singular recovery from set, which here amounts to 0.004 inches (0.01 cm.) in about 16 hours.

The last set of records here given are those of a bar of pure copper, made and tested for the U. S. Board,* and show well what may be expected of good copper castings, even without special fluxing or other unusual treatment. This bar was strong, carrying nearly 30 000 pounds per square inch (21.09 kilogs. per sq. cm.) in tension, but it lacked ductility, a consequence of the presence of copper oxide.

In the working of copper in the foundry the melter is sure to meet with difficulty from the formation of either the oxide or carbide. Could he secure immunity from the danger of combination with one or the other of these elements, he would find innumerable uses for cast copper. One of the discoveries to be looked for, and to be hoped for, is a method of securing pure cast copper. The stronger affinities of the metal, when molten, make this problem a more difficult one than that of obtaining sound steel castings. The transverse strength of the metal seemed to have been less reduced by the presence of the oxide than was its tenacity. The fact that the bar could be broken at all in the transverse testing machine is evidence of reduction of ductility due to this cause. The record of the compression test seems to indicate that form of resistance due to the presence of oxide.

The general character and the method of variation of strength and ductility of the alloys of copper, tin and zinc are so well exhibited by the illustrations which have been presented in these papers, that it is the hope of the writer that no difficulty will be met with by the engineer in the endeavor to select the alloy best adapted to any specific purpose where such an adaptation is determined by physical qualities alone.

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*See Report of 1878.

Caution must be used in selecting alloys where great strength is demanded, since a slight change of composition by the addition of tin or zinc may make a serious change in the direction of lessened ductility and toughness. The engineer will rarely use those lying on the tin and zinc side of the line of alloys having 0.07 (7 per cent.) ductility, as on Figs. 1 and 2. Extraordinary care must also be taken in making the strongest of these alloys.

Alloys to be hammered or rolled will be found more difficult to work as the percentage of tin is increased, and the minutest addition of tin to the brasses usually rolled is found to sensibly decrease their manageability.

RECORDS OF TESTS MADE AT THE

Mechanical Laboratory, Department of Engineering,

Stevens Institute of Technology.

Material, Bronze :
Copper.....89,974%
Tin.....9,997%
Flux, &c..... 0,029%

1. RECORD ACCOMPANYING AUTOGRAPHIC STRAIN DIAGRAMS.

Gun Bronze.

Lab. No.	Size for Estimates.		Stresses in Torsion. Foot-pounds.		Elasticity.	Elastic Resilience.	Ratio of Extension.		Homogeneousness as to		Stiffness.	Resilience. W	Modulus of Resistance Torsion. (A)			Angle.	
	Length. L	Diameter. H	Proof. M′	Ultimate. M			Proof.	Maximum.	Structure.	Strain.			Elastic. $A^E = \frac{M'L}{H^5 \Theta_E}$	Proof. $A' = \frac{M'}{H_3}$	Ultimate $A = \frac{M}{H_3}$	Θ_E	Θ_R
1252B	1″	.625″	49.03	99.83	.00717	0.38	.000013	.04737	Ex.	Ex	54.5	84.60	571.2	200.94	409.1	0.9°	57.2
1252B$_2$	"	"	71.71	127.05	.00776	1.55	.000089	.07554	"	"	29.9	138.66	313.3	293.9	520.7	2.4°	72.6

2. RECORDS OF TESTS BY TENSION.

Copper.. . 89.974%
Tin..... 9.997% GUN BRONZE.
Flux, &c.. 0.029% Lab. No. 1252A²

Dimensions. Original and Final.		Stresses.		Proof Load per Square Inch Area of	Breaking Load per Square Inch.	Extension.		Modulus of Elasticity. E	Modulus of Resilience. W
Length. L, L′	Diameter. H, H′	Proof.	Ultimate.	Original Section. P	Original Section. T	Actual.	% of Original Length.		
5″	.798″	150	.....	300	.....	.....	.....	11 467 763	
.....	.....	1000	.....	2000	.....	.0008	.016%		
.....	.....	2000	.....	4000	.....	.0016	.03		
.....	.....	3000	.....	6000	.....	.0024	.05		
.....	.....	4000	.....	8000	.....	.0036	.07		
Elastic	Limit.	5000	.....	10000	.....	.0047	.09	.....	0.98
.....	.....	6000	.....	12000	.....	.0063	.13		
.....	.....	7000	.....	14000	.....	.0080	.16		
.....	.....	8000	.....	16000	.....	.0112	.22		
.....	.....	9000	.....	18000	.....	.0166	.33		
.....	.....	10000	.....	20000	.....	.0263	0.53		
.....	.....	11000	.....	22000	.....	.0428	.86		
.....	.....	12000	.....	24000	.....	.0675	1.35		
.....	.....	13000	.....	26000	.....	.1009	2.045		
.....	.....	15000	.....	30000	.....	.2069	4.14		
.....	.....	.....	15500	.....	31000	.23	4.6	.....	242

3. RECORDS OF TESTS BY COMPRESSION.

Copper..... 89.974%
Tin..... 9.997% GUN BRONZE.
Flux, &c..... 0.029% Lab. No. 1252C_2.

Dimensions. Original and Final.		Stresses.	Proof Load per Square Inch Area of	Breaking Load per Square Inch.	Compression.		Resilience. W
Length. L, L′	Diameter. H, H′	Proof.	Original Section. P	Original Section. T	Actual.	% of Original Length.	Foot-Pounds.
2″	.625	150	.....	.....	.....	.....	
.....	.....	1000	.....	.....	0.0019″	0.09%	
.....	.....	2000	.....	.....	.0032	.16	
.....	.....	3000	.....	.....	.0033	.16	
.....	.....	4000	.....	.....	.0040	.20	
.....	.....	5000	.....	.....	.0048	.24	
.....	.....	6000	.....	.....	.0076	.38	
Elastic	Limit.	7000	22816	.....	.0117	.58	6.825
.....	.....	8000	.....	.....	.0227	1.13	
.....	.....	9000	.....	.....	.0385	1.92	
.....	.....	10000	.....	.....	.0609	3.04	
.....	.....	11000	.....	.....	.0867	4.33	
.....	.....	12000	.....	.....	.1163	5.81	
.....	.....	13000	.....	.....	.1494	7.47	
.....	.....	14000	.....	.....	.1794	8.97	
.....	.....	15000	.....	.....	.2110	10.55	
.....	.....	16000	.....	.....	.2402	12.01	
.....	.....	17000	.....	.....	.2678	13.39	
.....	.....	18000	.....	.....	.2989	14.94	
.....	.....	19000	.....	.....	.3229	16.14	
.....	.....	20000	.....	.....	.03599	17.99	
.....	.....	21000	.....	.....	.3904	19.52	
.....	.....	22000	.....	.....	.4164	20.82	
.....	.....	23000	.....	.....	.4478	22.39	
.....	.....	24000	.....	.....	.4870	24.35	
.....	.....	25000	.....	.....	.5092	25.46	
.....	.....	26000	.....	.....	.5409	27.04	
.....	.....	27000	.....	.....	.5706	28.53	
.....	.....	28000	.....	.....	.5999	29.99	
.....	.....	29000	.....	.....	.6235	31.17	
.....	.....	30000	.....	.....	.6460	32.30	
.....	.....	31000	.....	.....	.6694	33.47	
.....	.....	32000	.....	.....	.6904	34.52	
.....	.....	33000	.....	.....	.7125	35.62	
.....	.....	34000	.....	.....	.7311	36.55	
.....	.....	35000	.....	.....	.7517	37.58	
.....	.....	36000	.....	.....	.7726	38.63	
.....	.....	37000	.....	.....	.7914	39.57	
.....	.769	38000	.....	123860	.8115	40.57	1.480

4. RECORDS OF TESTS BY TRANSVERSE STRESS.

			Dimensions Original and Final.		
			Length.	Breadth.	Depth.
Copper...	89.974%	Gun Bronze.	l. l'.	b b'.	d. d'.
Tin ...	9.997%				
Flux, &c...	0.029%	Lab. No. 1252.	22″	1.020″	0.97″

	Proof Stresses.		Deflection.	Breaking Load.		Modulus of Elasticity.	Modulus of Resilience.
	Absolute. P_1	Modulus. $R_1 = \frac{3 P_1 l}{2 b d_2}$	Absolute. δ	Absolute. P	Modulus. $R = \frac{3 P l}{2 b d_2}$	$E = \frac{P l_3}{48 \delta 1}$.	W Ft. Lbs.
	3	.... ..	.. ..	.....	.....	13 487 264	
	10	.....	0.0016″				
	20	.....	.0036				
	40	.....	.0084				
	80	.....	.0179				
	120	.....	.0257				
	160	....	.0344				
	200	.....	.0429				
	3	....	.0012				
	240	.....	.0502				
	280	.....	.0581				
	320	.....	.0669				
	360	.....	.0761				
	400	.....	.0845				
	3	.....	.0034				
	440	.....	.0929				
	480	... .	.1015				
	520	.....	.1102				
	560	.....	.1192				
	600	.....	.1277				
	3	.....	0.0054				
	640	.....	.1364				
Elastic Limit.	680	23 375	.1463	.....	.....	.....	4.145
	720	....	.1594				
	760	.....	.1717				
	800	.....	.1879				
	3	.....	.0276				
	840	....	.2039				
	880	....	.2219				
	920	.....	.2475				
	960	.....	.2832				
	1000	.....	.3310				
	3	.....	.1248				
	1040	... .	.3841				
	1080	.....	.4426				
	1120	.....	.5359				

4. RECORDS OF TESTS BY TRANSVERSE STRESS.—*Continued.*

Copper ... 89.974%
Tin... .... 9.997%
Flux, &c... 0.029%

GUN BRONZE.

Lab. No. 1252.

Dimensions Original and Final.		
Length.	Breadth.	Depth.
$l.\ l'$	$b.\ b.'$	$d.\ d'.$
22″	1.020″	0.97″

	Proof Stresses.		Deflection.	Breaking Load.		Modulus of Elasticity.	Modulus of Resilience.
	Absolute. P_1	Modulus. $R_1 = \frac{3\ P_1\ l}{2\ b\ d_2}$	Absolute. δ	Absolute. P	Modulus. $R = \frac{3\ P\ l}{2\ b\ d_2}$	$E = \frac{P\ l_3}{48\ \delta\ I}$	W Ft. Lbs.
	1160	.....	.6492″				
	1200	.....	.7774				
	3	.....	.5114				
	1240	.....	.9043				
	1280	....	1.027				
	1320	.....	1.1998				
	1360	.....	1.407				
	1400	.....	1.694				
	3	.....	1.2008				
	1440	.....	1.835				
	1480	.....	2.020				
	1520	.....	2.237				
	1560	....	2.553				
	1600	.....	3.1108				
	3	.....	2.462				
	1640	... .	3.358	1640	56 375	.....	327.5

5. RECORD OF TESTS BY TENSION.

Copper.. 80%
Zinc 20%

ALLOY OF COPPER AND ZINC.

Lab. No. 585B.

Dimensions. Original and Final.	
Length. L, L′	Diameter. H, H′
5″	.798

Stresses.		Proof Load per Square Inch Area of		Breaking Load per Square Inch.		Extension.
Proof.	Ultimate.	Original Section. P	Fractured Section. P′	Original Section. T	Fractured Section. T′	Actual.
4800	.....	.....	.....	.....	.....	.0018
5000	.....	.....	.....	.....	.....	.0037
5200	.....	.....	.....	.....	.....	.0075
5400	.....	.....	.....	.....	.....	.0132
5600	.....	.....	.....	.....	.....	.0205
6000	.....	.....	.....	.....	.....	.0385
220	.....	.....	.....	.....	.....	.0127
6400	.....	.....	.....	.....	.....	.0622
6800	.....	.....	.....	.....	.....	.0904
8000	.....	.....	.....	.....	.....	.1849
8800	.....	.....	.....	.....	.....	.2450
9600	.....	.....	.....	.....	.....	.2979
10400	.....	.....	.....	.....	.....	.3530
11200	.....	.....	.....	.....	.....	.4495
11600	.....	.....	.....	.....	.....	.4880
12000 (*a*)	.....	.....	.....	.....	.....	
16750 (*b*)	16750	33140	55599	33140	55599	

(*a*.) Micrometer slipped, further reading of no value.
(*b*.) Total elongation, measured after breaking 1.62″

6. RECORD OF TESTS BY TRANSVERSE STRESS.

		Dimensions.		
		Distance between Supports.	Breadth. b.	Depth d.
Copper....80% Zinc.....20%	Alloy of Copper and Zinc. Lab. No. 585	22″	.995	.985

Proof Stresses	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2db_2}$	$E=\frac{Pl_3}{48\delta I}$
10	.0042	.....	.....	
40	.0124	.....	.....	9030560
80	.0206	.....	.....	10708667
120	.0296	.....	.....	11349217
160	.0363	.....	.....	12339278
200	0449	.....	.....	12469814
3	.0056			
240	.0544	.....	.....	12530618
280	.0692	.....	.....	11327350
320	.0980	.....	.....	9141138
360	.1659	.....	.....	6074807
400	.3288	.....	.....	3405686
3	.2445			
400	.3352			
420	.4414			
440	.5885			
460	.7520			
480	.9590			
500	1.1763	.....	.....	1189949
520	1.5463			
540	1.6163			
560	1.86			
580	2.22			
600	2.62			
620(*a*)	3.27	620	21193	

(*a*.) Bent down without breaking ; bar removed.

Fracture, " Surface in character resembling No. 584, but less jagged." Color : brass yellow.

7. RECORD OF TESTS BY TENSION.

Copper.... 62.5% Alloy of Copper and Zinc.
Zinc..... 37.5% Lab. No. 609A.

Dimensions. Original and Final.		Stresses.		Proof Load per Square Inch Area of		Breaking Load per Square Inch.		Extension.
Length. L, L′	Diameter. H, H′	Proof.	Ultimate.	Original Section. P	Fractured Section. P′	Original Section. T	Fractured Section. T′	Actual.
5″	.798	500	.....	.....	.....	.....	.....	.0003
.....	.....	1000	.....	.....	.....	.....	.....	.0007
.....	.....	1500	.....	.....	.....	.....	.....	.0010
.....	.....	2000	.....	.....	.....	.....	.....	.0016
.....	.....	3000	.....	.....	.....	.....	.....	.0024
.....	.....	4000	.....	.....	.....	.....	.....	.0037
.....	.....	5000	.....	.....	.....	.....	.....	.0052
.....	.....	6000	.....	.....	.....	.....	.....	.0066
.....	.....	100	.....	.....	.....	.....	.....	.0008
.....	.....	7000	.....	.....	.....	.....	.....	.0087
.....	.....	8000	.....	.....	.....	.....	.....	.0123
.....	.....	100	.....	.....	.....	.....	.....	.0047
.....	.....	9000	.....	.....	.....	.....	.....	.0185
.....	.....	10000	.....	.....	.....	.....	.....	.0447
.....	.....	100	.....	.....	.....	.....	.....	.0359
.....	.....	11000	.....	.....	.....	.....	.....	.0810
.....	.....	12000	.....	.....	.....	.....	.....	.1290
.....	.....	100	.....	.....	.....	.....	.....	.1162
.....	.....	13000	.....	.....	.....	.....	.....	.1782
.....	.....	14000	.....	.....	.....	.....	.....	.2375
.....	.....	100	.....	.....	.....	.....	.....	.2197
.....	.....	15000	.....	.....	.....	.....	.....	.3148
.....	.....	16000	.....	.....	.....	.....	.....	.3877
.....	.....	100	.....	.....	.....	.....	.....	.3650
.....	.....	16500	.....	.....	.....	.....	.....	.4334
.....	.....	17500(*a*)	.....	.....	.....	.....	.....	.....
.....	.670	24380(*b*)	24380	48760	68979	48760	68979	1.55″

(*a*). Micrometer slipped.

(*b*). Broke 2 inches from "C" end. Fracture; light brownish yellow, very compact, diagonal surfaces slightly polished. Several times during the test a dull sound was heard from the piece, and at the same instant the resistance decreased, in one instance to the extent of 1 300 pounds.

8. RECORD OF TESTS BY TRANSVERSE STRESS.

Copper....62.5% Zinc.....37.5%	Alloy of Copper and Zinc. Lab. No. 608.	Dimensions. Distance between Supports.	Breadth. b.	Depth. d.
		22″	.970	.972

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R = \frac{3 P l}{2 b d_2}$	$E = \frac{P l_3}{48 \delta I}$
10	.0044	.....	.....	
20	.0061	....	.....	
40	.0078	.....	.....	15325081
80	.0167	.....	.....	14315643
120	.0244	.....	.....	14697004
160	.0327	.....	.....	14622094
200	.0417	.....	.....	14332809
3	.0040	.....	.....	
240	.0506	.....	..	14174185
280	.0598	.....	.....	13992465
320	.0690	.....	.....	13859204
360	.0775	.....	.....	13881558
400	.0874	.....	.....	13677164
3	.0023	.....	.....	
440	.0958	.....	.....	13757029
480	.1028	.....	.....	13953576
520	.1102	.....	.....	14101299
560	.1198	.....	.....	13969106
600	.1318	.....	.....	13604210
3	.0048	.....	.....	
640	.1493	.....	.....	12810242
680	.1630	.....	..	
720	.1832	.....	.....	11771840
760	.2130	.....	.....	
800	.2628	.....	.....	9097079
3	.0760	.....	.....	
840	3160	.....	.....	
880	.4461	.....	.....	
920	.6000	.....	.....	4978218
960	.7782	.....	.....	
1000	.8927	.....	.....	3347588
3	.7277	.....	.....	
1040	1.1753	.....	...	
1080	1.53	.....	.....	2109413
1120	1.88	.....	.....	
1160	2.23	.....	.....	
1200 (*a*)	3.13	1 200	43 216	1145709

(*a*) Bar bent down without breaking.

9. RECORD OF TESTS BY TENSION.

Triple Alloy of Copper, Tin and Zinc.

Copper.... 58.22%
Tin..... 2.30%
Zinc..... 39.48%

Tobin's Alloy.

Lab. No. 856B.

Dimensions. Original and Final.	
Length. L, L′	Diameter. H, H′
5″	.798

Stresses.		Breaking Load per Square Inch.		Extension.
Proof.	Ultimate.	Original Section. T	Fractured Section. T′	Actual.
150	.....	.....	.....	.0
500	.....	.....	.....	.0012
1000	.....	.....	.....	.0022
1100	.....	.....	.....	.0024
1200	.....	.....	.....	.0026
1300	.....	.....	.....	.0028
1400	.....	.....	.....	.0030
1500	.....	.....	.....	.0032
1600	.....	.....	.....	0034
1700	.....	.....	.....	.0036
1800	.....	.....	.....	.0038
1900	.....	.....	.....	.0041
2000	.....	.....	.....	.0044
2500	.....	.....	.....	.0054
3000	.....	.....	.....	.0064
3500	.....	.....	.....	0074
4000	.....	.....	.....	.0081
4500	.....	.....	.....	.0088
5000	.....	.....	.....	.0095
150	.....	.....	.....	.0022
5000	.....	.....	.....	.0113
6000	.....	.....	.....	.0125
7000	.....	.....	.....	.0137
8000	.....	.....	.....	.0150
9000	.....	.....	.....	.0165
10000	.....	.....	.....	.0176
11000	.....	.....	.....	.0189
12000	.....	.....	.....	.0202
13000	.....	.....	.....	.0213
14000	.....	.....	.....	.0226
15000	.....	.....	.....	.0240
16000	.....	.....	.....	.0254
17000	.....	.....	.....	.0268
18000	.....	.....	.....	.0282

9. RECORD OF TESTS BY TENSION.—(*Continued.*)

Triple Alloy of Copper, Tin and Zinc.

Copper.... 58.22%
Tin..... 2.30%
Zinc..... 39.48%

Tobin's Alloy.

Lab. No. 856B.

Dimensions. Original and Final.	
Length. L, L′	Diameter. H, H′
5″	.798

Stresses.		Breaking Load per Square Inch.		Extension.
Proof.	Ultimate.	Original Section. T	Fractured Section. T′	Actual.
19000	.....	.....	.....	.0297
20000	.....	.....	.....	.0313
150	.....	.....	.....	.0150
5000	.....	.....	.....	.0215
10000	.....	.....	.....	.0279
15000	.....	.....	.....	.0345
20000	.....	.....	.....	.0399
21000	.....	.....	.....	.0423
22000	.....	.....	.....	.0447
23000	.....	.....	.....	.0473
24000	.....	.....	.....	.0494
25000	.....	.....	.....	.0527
26000	.....	.....	.....	.0568
27000	.....	.....	.....	.0615
28000	.....	.....	.....	.0674
29000	.....	.....	.....	.0771
30000	.....	.....	.....	.0873
31000	.....	.....	.....	.0958
32000	.....	.....	.....	.1277
33000	.....	.....	.....	.1577
33800(*a*)	33800	67600	73160	.....

(*a*.) Broke. Fracture : yellowish gray, with light pinkish shade. Open granular structure, with a few very minute blow holes, several lustrous points scattered over the surface. No radiated lines were seen like those of the transverse fracture.

10. RECORD OF TESTS BY TRANSVERSE STRESS.

Triple Alloy of Copper, Tin and Zinc.		Dimensions. Distance between Supports.	Breadth. b.	Depth. d.
Copper . 58.22%				
Tin 2.30%	Tobin's Alloy.			
Zinc 39.48%				
	Lab. No. 856.	22″	1.010	.992

Proof Stresses. Absolute. P_1	Deflection. Actual.	Breaking Load. Absolute. P	Breaking Load. Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$	Modulus of Elasticity. $E=\frac{P\,l_3}{48\,\delta\,I}$
3				
10	0.0024			
20	0.0046	.....	.....	11760504
40	0.0098	.....	.....	11040471
80	0.0202	.....	.....	11712635
120	0.296	.....	.....	10965874
160	0.418	.....	.....	10353743
200	0.0517	.....	.....	10643891
10	.0032			
3	.0011			
200	.0532			
240	.0612	.....	.....	10607511
280	.0712	.....	.....	10637306
320	.0802	.....	.....	10792679
360	.0908	.....	.....	10724336
400	.1000	.....	.....	10819661
10	.0027			
3	.0008			
400	.1010			
440	.1095	.....	.....	10869067
480	.1197	.....	.....	10846777
520	.1294	.....	.....	10869829
560	.1403	.....	.....	11578364
600	.1511	.....	.....	14321161
10	.0032			
3	.0015			
600	.1515			
640	.1629	.....	.....	10627046
680	.1740	.....	.....	10570934
720	.1846	.....	.....	10550048
760	.1944	.....	.....	10574771
800	.2038	.....	.....	10617922
10	.0043			
3	.0032			
800	.2028			
840	.2142	.....	.....	10607511
880	.2247	.....	.....	10593349
920	.2344	.....	.....	10616562

10. RECORD OF TESTS BY TRANSVERSE STRESS.—(*Continued.*)

Triple Alloy of Copper, Tin and Zinc.		Dimensions.		
Copper . 58.22%		Distance between Supports.	Breadth. b.	Depth. d.
Tin 2.30%	Tobin's Alloy.			
Zinc. . . . 39.48%				
	Lab. No. 856.	22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2b\,d_2}$	$E=\frac{P\,l_3}{48\,\delta\,I}$
960	.2433	.....	.....	10672909
1000	.2550	.....	.....	10607511
10	.0064			
3	.0046			
1000	.2544			
1040	.2642	.....	.....	10647661
1080	.2764	.....	.....	10569132
1120	.2847	.....	.....	10641044
1160	.2951	.....	.....	10632674
1200	.3062	.....	.....	10600509
10	.0114			
3	.0093			
1194*	.3069			
1240	.3170			
1280	.3276			
1320	.3398			
1360	.3528			
1400	.3673	.....	.....	10310049
10	.0210			
3	.0193			
1400	.3695			
1440	.3817			
1480	.3959			
1520	.4102			
1560	.4236			
1600	.4395	.....	.....	9847245
10	.0407			
3	.0387			
1600	.4405			
1640	.4537			
1680	.4704			
1720	.4882			
1760	.5042			
1800	.5205	.....	.....	9354174
10	.0743			
3	.0727			

* After 55 minutes resistance decreased from 1200 to 1194 pounds.

10. RECORD OF TESTS BY TRANSVERSE STRESS.—(*Continued.*)

Triple Alloy of Copper, Tin and Zinc.		Dimensions.		
		Distance between Supports.	Breadth. *b.*	Depth. *d.*
Copper . 58.22%				
Tin 2.30%	Tobin's Alloy.			
Zinc. . . . 39.48%				
	Lab. No. 856.	22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$	$E=\frac{P\,l_3}{48\,\delta\,I}$
1800	.5230			
1840	.5383			
1880	.5586			
1920	.5823			
1960	.6076			
2000	.6343			
10	.1340			
3	.1326			
8 (*a*)				
3	.1320			
2000	.6390	. . . . .	. . . . .	8955262
2040	.6594			
2080	.6856			
2120	.7140			
2160	.7456			
2200	.7777	. . . . .	. . . . .	7651812
2240	.8106			
2280	.8621			
2272 (*b*)	.8621			
2268 (*c*)	.8621			
2260 (*d*)	.8621			
2256 (*e*)	.8621			
2288 (*f*)	.8665 (*f*)			
2290	.8658			
2300	.8722			
2310	.8763			
2320 (*g*)	.8843 (*g*)			
2312 (*h*)	.8843			
2309 (*i*)	.8843			

(*a*) After 10 minutes resistance increased from 3 to 8 pounds.
(*b*) " 1 " " decreased " 2280 " 2272 "
(*c*) " 3 " " " " " " 2268 "
(*d*) " 25 " " " " " " 2260 "
(*e*) " 60 " " " " " " 2256 "
(*f*) to (*g*) presents slight elevation of Elastic Limit.
(*h*) Resistance decreased in 3 minutes from 2320 to 2312 pounds.
(*i*) " " " 10 " " " " 2309 "

10. RECORD OF TESTS BY TRANSVERSE STRESS.—(*Continued.*)

Triple Alloy of Copper, Tin and Zinc.		Dimensions.		
Copper . 58.22%		Distance between Supports.	Breadth. b.	Depth. d.
Tin 2.30%	Tobin's Alloy.			
Zinc. . . 39.48%				
	Lab. No. 856.	22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$	$E=\frac{P\,l_3}{48\,\delta\,I}$
2260 (*j*)	8770 (*k*)			
2270	.8867			
2280	.8893			
2290	.8919			
2300	.8948			
2310	.8967			
2320	.8990			
2330	.9019			
2340	.9063			
2350	.9165			
2342 (*l*)	.9165			
2350	.9189			
2360	.9239			
2370	.9418			
2380	.9529			
2390	.9650			
2400	.9764			
2410	.9888			
2420	1.0048			
2430	1.0189			
2440	1.0333			
2450	1.0438			
2460	1 0553			
2470	1 0755			
2480	1.0865			
2490	1 1013			
2500	1.1265			
2510	1.1341			
2520	1.1475			
2530	1.1647			
2540	1.1818			
2550	1.1918			
2560	1 2073			

(*j*) Resistance decreased in 66 hours 13 minutes from 2320 to 2260 pounds.

(*k*) Reading of extension apparatus changed, so as to correspond to deflection of 8770—probably caused by gradual set of machine under the constant strain, and compression or bending of the lower transverse timber.

(*l*) Resistance decreased in ten minutes from 2350 to 2342 pounds.

10. RECORD OF TESTS BY TRANSVERSE STRESS.—(*Continued.*)

Triple Alloy of Copper, Tin and Zinc.		Dimensions.		
Copper . 58.22%		Distance between Supports.	Breadth. *b.*	Depth. *d.*
Tin 9.30%	Tobin's Alloy.			
Zinc. . . . 39.48%				
	Lab. No. 856.	22″	1.010	.992

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\ P\ l}{2\ b\ d_2}$	$E=\frac{P\ l_3}{48\ \delta\ I}$
2570	1.2293			
2580	1.2445			
2590	1.2585			
2600	1.2851	.....	.....	5472552
2610	1.3063			
2620	1.3288			
2630	1.3406			
2640	1.3556			
2650	1.3747			
2660	1.3973			
2670	1.4178			
2680	1.4447			
2690	1.4665			
2700	1.4898			
2720	1.5057			
2730	1.5303			
2740	1.5603			
2750	1.6106			
2760	1.6279			
2770	1.6395			
2780	1.6581			
2790	1.6899			
2800	1.7285	.....	.....	4331697
2810	1.7599			
2820	1.7793			
2830	1.8111			
2840	1.8553			
2850	1.8807			
2860	1.8936			
2870	1.9453			
2880	1.9881			
2890 (*m*)	.....	2880	95623	

(*m*) Broke in the middle in putting on strain. Gave warning by a slight crackling sound a few seconds before breaking, and broke gradually.

Fracture: Yellowish gray, with slight pinkish tinge, somewhat like brass alloy No. 612, but more yellow. Coarse granular structure, with radiated fibres near the edges. Slightly lustrous. Fractured section—trapezoidal.

11. RECORD OF TESTS BY TRANSVERSE STRESS.

		Dimensions.		
Copper....55.00% Tin ..... 0.50% Zinc.....44.50%	Triple Alloy of Copper, Tin and Zinc. Lab. No. 1001.	Distance between Supports.	Breadth. b.	Depth. d.
		22″	1.″	.979″

Proof Stresses.	Deflection.	Breaking Load.	
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$
3			
10	.0021		
20	.0051		
40	.0122		
80	.0417		
120	.0321		
160	.0417		
200	.0519		
10	.0024		
3	.0004		
200	.0520		
240	.0631		
280	.0734		
320	.0813		
360	.0899		
400	.1001		
10	0.0028		
3	.0008		
400	.0997		
440	.1102		
480	.1199		
520	.1300		
560	.1402		

11. RECORD OF TESTS BY TRANSVERSE STRESS.—(*Continued.*)

		Dimensions.		
Copper....55.00% Tin..... 0.50% Zinc.....44.50%	Triple Alloy of Copper, Tin and Zinc. Lab. No. 1001.	Distance between Supports.	Breadth. *b.*	Depth. *d.*
		22″	1.″	.979″

Proof Stresses.	Deflection.	Breaking Load.	
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3\,P\,l}{2\,b\,d_2}$
600	.1516		
10	.0046		
3	.0018		
600	1518		
640	.1623		
680	.1745		
720	.1881		
760	.2024		
800	.2164		
10	.0140		
3	.0119		
800	.2167		
840	.2296		
880	.2443		
1400 3(*a*)	.3089		
10	.3097		
3	.3057		
.....	.....	2100	72308

(*a.*) No. 1001 (55 Cu. 0.5 Sn, 44.52 n.) The scale beam could not be raised by applying more pressure after 2 100 pounds was reached, This was due to the rapid bending of the bar, which, however, could not be broken until it was nicked with a saw on all sides. The casting was not very sound externally, and the corners were somewhat rounded, owing to the metal not having filled the mould completely. After 1 400 lbs. was reached and applied, a test was made to determine the recovery from set with time. When balanced at 3 lbs. the micrometer read 0.3089″. After 20 minutes the scale beam balanced at 5½ lbs., and after 15 hrs. 45 minutes at 10 lbs. The reading of the micrometer was again taken, it being this time 0.3094″, showing a difference of .0005, which may be ascribed to the gradual recovery or springing back of the wooden frame of the machine after it was relieved from pressure. When the pressure of 5.5 lbs. was taken off and the scale beam again balanced at 3 lbs., a reading of 0.3057 was obtained, which indicates a recovery from set of 0.3094″—0.3057″=0.0037″ in 15¾ hours.

12. RECORD OF TESTS BY TENSION.

Copper, cast very hot. Lab. No. 581A.

Cast Copper.

Dimensions. Original and Final.	
Length. L, L′	Diameter H, H′
5″	.798

Stresses.		Proof Load per Square Inch Area of		Breaking Load per Square Inch.		Extension.
Proof.	Ultimate.	Original Section. P	Fractured Section. P′	Original Section. T.	Fractured Section. T′	Actual.
400	.....	.....	.....	.....	.....	.0004
600	.....	.....	.....	.....	.....	.0007
1000	.....	.....	.....	.....	.....	.0011
2000	.....	.....	.....	.....	.....	.0022
3000	.....	.....	.....	.....	.....	.0025
4000	.....	.....	.....	.....	.....	.0027
5000	.....	.....	.....	.....	.....	.0026
6000	.....	.....	.....	.....	.....	.0032
6800	.....	.....	.....	.....	.....	.0083
7200	.....	.....	.....	.....	.....	.0132
8000	.....	.....	.....	.....	.....	.0358
8400	.....	.....	.....	.....	.....	.0492
8800	.....	.....	.....	.....	.....	.0642
9200	.....	.....	.....	.....	.....	.0792
9600	.....	.....	.....	.....	.....	.0942
9800	.....	.....	.....	.....	.....	.1073
250	.....	.....	.....	.....	.....	.0951
9800	.....	.....	.....	.....	.....	.1082
10200	.....	.....	.....	.....	.....	.1218
10600	.....	.....	.....	.....	.....	.1408
11000	.....	.....	.....	.....	.....	.1605
11400	.....	.....	.....	.....	.....	.1794
11800	.....	.....	.....	.....	.....	.2008
12200	.....	.....	.....	.....	.....	.2191
12600	.....	.....	.....	.....	.....	.2405
13000	.....	.....	.....	.....	.....	.2626
14000	.....	.....	.....	.....	.....	.3258
270	.....	.....	.....	.....	.....	.3155
14000	.....	.....	.....	.....	.....	.3270
14400	.....	.....	.....	.....	.....	.3448
14600 (*a*)	14600	29200	34790	29200	34790	.3760

(*a*.) Broke while reading was being taken. Broke ¼ inch from "A" end. The fractured section distorted from circular form. Three diameters measured .737″ .725″ and .732.″ Fracture: fine, fibrous looking, radiated and compact. Strongest piece of copper yet tested.

13. RECORD OF TESTS BY TRANSVERSE STRESS.

Copper, cast very hot.

Lab. No. 581.

Cast Copper.

Dimensions.		
Distance between supports.	Breadth. b	Depth. d
22″	.990	.980

Proof Stresses.	Deflection.	Breaking Load.		Modulus of Elasticity.
Absolute. P_1	Actual.	Absolute. P	Modulus. $R=\frac{3Pl}{2bd_2}$	$E=\frac{Pl_3}{48\delta 1}$
10	0.0033			
40	.0116	.....	.....	9851369
80	.0224	.....	.....	10203205
120	.0355	.....	.....	9657120
160	.0513	.....	.....	8910400
200	.0729	.....	.....	7837853
5	.0260			
240	.0964	.....	.....	7112607
280	.1280			
320	.1705	.....	.....	5361919
360	.2253			
400	.3079	.....	.....	3711460
5	.2040			
440	.4169			
480	.5565			
520	.7540	.....	.....	1970274
560	.9155			
600	1.1635			
5	1.0085			
600	1.2105			
640	1.37			
680	1.63			
720	1.93	.....	.....	1065786
760	2.23			
800	2.60			
820	2.83			
840	3.09			
860 (*a*)	3.49	.....	.....	720375
1150 (*b*)	5.74			
3000 (*c*)	8.00	3000	29848	

(*a*) The supports slipped. Placed the bar on cast iron fixed supports 20 inches apart, and (*b*) 1 150 lbs. gave it a further deflection of 2¼ inches. Moved the supports to 10 inches, and applied (*c*) 3 000 lbs., when bar broke, the total deflection being about 8 inches.

Fracture: Coarsely fibrous and radiate from centre of surface of fracture. Color: Dark red from superficial oxidation. Fibres interrupted and covered over with minute ridges, with sharp lines of separation.

14. RECORD OF TESTS BY COMPRESSION.

Copper, cast very hot. CAST COPPER.

Lab. No. 581.

DIMENSIONS. Original and Final.		STRESSES.		PROOF LOAD Per Square Inch Area of Original Section.	BREAKING LOAD Per Sq. Inch Original Section.	COMPRESSION.
Length. L, L′	Diameter H, H′	Proof.	Ultimate.	P	T	Actual.
2″	.625	500	.....	.....	.....	.0026
.....	.....	1000	.....	.....	.....	.0046
.....	.....	2000	.....	.....	.....	.0079
.....	.....	3000	.....	.....	.....	.0109
.....	.....	4000	.....	.....	.....	.0143
.....	.....	5000	.....	.....	.....	.0177
.....	.....	6000	.....	.....	.....	.0212
.....	.....	7000	.....	.....	.....	.0263
.....	.....	8000	.....	.....	.....	.0347
.....	.....	9000	.....	.....	.....	.0513
.....	.....	10000	.....	.....	.....	.0801
.....	.....	11000	.....	.....	.....	.1187
.....	.....	12000	.....	.....	.....	.1619
.....	.....	13000	.....	.....	.....	.2053
.....	.....	14000	.....	.....	.....	.2508
.....	.....	15000	.....	.....	.....	.2942
.....	.....	16000	.....	.....	.....	.3373
.....	.....	17000	.....	.....	.....	.3373
.....	.....	18000	.....	.....	.....	.4722
.....	.....	19000	.....	.....	.....	.4688
.....	.....	20000	.....	.....	.....	.5100
.....	.....	21000	.....	.....	.....	.5594
.....	.....	22000	22000	71709	71709	.6415

ERRATA.

Vol. X, Jan. 1881, No. CCXIV.

The Strongest of the Bronzes.

Page 2, line 6 ; *read* equilateral triangle.
Page 2, line 14 ; *for* "isoceles," *read* equilateral.
Page 8, line 8 from bottom ; *for* "liquidation," *read* liquation.
Page 9, line 9, *for* "Sn., 2.5," *read* Sn. 0.5.
Page 11, line 19 ; *for* "4 *t*, *read* 3 *t* ;" and *for* "50," *read* 55.
Page 11, line 21 ; *for* "50," *read* 55.
Page 11, line 22 ; *for* "12.5," *read* 18.

The body of this paper will be devoted to a detail of actual experience in shaft building under difficult circumstances, but that the existing local conditions may be better understood, we will commence by a short general sketch of the work with which these shafts are immediately connected.

14. RECORD OF TESTS BY COMPRESSION.

Copper, cast very hot. CAST COPPER.

Lab. No. 581.

DIMENSIONS. Original and Final.		STRESSES.		PROOF LOAD Per Square	BREAKING LOAD	COM-
.....	.....	17000	.....	.....	.....	.3373
.....	.....	18000	.....	.....	.....	.4722
.....	.....	19000	.....	.....	.....	.4688
.....	.....	20000	.....	.....	.....	.5100
.....	.....	21000	.....	.....	.....	.5594
.....	.....	22000	22000	71709	71709	.6415

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications

CCXXIX.

(Vol. X.—October, 1881.)

SHAFT SINKING UNDER DIFFICULTIES AT DORCHESTER BAY TUNNEL, BOSTON, MASS.

By D. McN. STAUFFER, Member A. S. C. E.

READ SEPTEMBER 21ST, 1881.

The body of this paper will be devoted to a detail of actual experience in shaft building under difficult circumstances, but that the existing local conditions may be better understood, we will commence by a short general sketch of the work with which these shafts are immediately connected.

The system of improved sewerage, now being carried out by the City of Boston, is too extensive and complex in its ramifications to be treated of in this paper; we will therefore begin at the Pumping Station on Old Harbor Point, the terminus of the low-grade intercepting sewers.

The sewage, in passing from the pumping station to the point of final delivery, on Moon Island, must cross under Dorchester Bay, a navigable arm of Boston Harbor, about two miles wide from shore to shore, and to this end an inverted syphon or submarine tunnel becomes necessary.

After an examination into the geological formation of this region, it was determined to locate the horizontal portion of the syphon at a sufficient depth below the surface of the water to be entirely contained *within* the rock which was found to underlie the bay. This determination fixed the average invert grade of the finished tunnel about 142 feet below mean low tide, or Boston City datum. The ship channel is only 18 feet deep at low water, but the material overlying the rock was mud, clay, sand and gravel, so irregular in its deposit, and so unreliable in its general character, that tunnelling through it was an impossibility with the Atlantic ocean practically overhead.

The rock to be passed through belongs to the clay-slates, with, so far, infrequent strata of very hard conglomerates. But at some remote period this ancient sea floor, in taking its present trough-like shape, has been subjected to enormous pressures, much disturbing the original stratification, breaking the beds in many places and leaving them tilted at high angles to the horizon. The numerous faults consequent on this action, have been generally well filled again by injected material, but crevices, fortunately slight in extent, are frequent, which communicate more or less directly with a water-bearing stratum of sand, gravel and boulders, which seems to be continuous over the surface of the rock. Wherever cut by the tunnel section, these seams allow a greater or less percolation of sea water into the workings below, amounting at this date (July, 1881), to 1½ millions of gallons daily, which can, of course, only be removed by constant pumping; the length of tunnel now excavated being 4 600 feet.

Plate XLIV, is a general profile of the tunnel, and shows the rock dipping rapidly from east to west. To meet this rock at as high an elevation as possible, the western, or inlet shaft, was pushed out about 1 400 feet from the Boston shore of the bay, and connection made between it and the pumping station, by a high-grade tank sewer, founded

upon an embankment, and protected by rip-rap and a sea-wall. Four pumps, of a capacity of 25 million gallons each, daily, will raise the sewage a height of about 43 feet, and deliver it into this tank-sewer, the invert grade of which is $15\frac{5}{10}$ feet above city datum. This tank is double, each section being 8 feet wide by 16 feet high, and the interior is provided with a series of dams, which will intercept any heavy material that may pass through the screens provided at the entrance to the pump well. Either compartment of the tank can be shut off by gates, and cleaned, and by means of stop planks, the velocity head can be greatly increased, and the tank sewer used to flush out the tunnel, sea water being pumped into the tank for this purpose.

At the Inlet Shaft, the bottom of which is 142 feet below datum, the tunnel commences, and runs in a south-eastwardly direction for a distance of 6 090 feet, to the centre of the East Shaft, the bottom of which is 144 feet below datum; at this latter point the tunnel grade commences to rise at the rate of one foot vertical in six feet horizontal, and continues at this grade for a further horizontal distance of 903 feet, until the tunnel pierces the surface of the ground on Squantum Head, which forms the eastern side of Dorchester Bay.

At the eastern terminus of the tunnel, the invert grade is $14\frac{4}{10}$ feet above datum, and from this point the sewer is continued in an open cut across Squantum Head, and then on an embankment over the shoal water lying between the Head and Moon Island, to the collecting basin on the island, from which basin the sewage is emptied into the bay at each ebb tide by an appropriate system of gates and outfall chambers. The point of discharge is four and one-half miles in a direct line from the State House in Boston.

Dimension of Tunnel and Shafts.—The tunnel and the shafts are circular in section, with a finished inside diameter of 7 feet 6 inches. The tunnel and shaft excavation, as at first taken out, is as near as may be, 9 feet 6 inches in diameter, provision being thus made for a final lining of brick-work throughout, 12 inches thick, for the purpose of reducing friction. This brick-work is intended to be water-tight, and at the inlet shaft, gates and an outfall sewer will be built, leading from the tank sewer, so that the sewage can be discharged directly into the bay at this point, and the tunnel pumped out, examined and cleansed, when such a proceeding may be deemed necessary. To intercept any solid matter that may pass into the tunnel, a sump, 6 feet deep is provided at

the bottom of the East Shaft, and consequently at the foot of the Incline, from which sump the material may be removed by dredging through the shaft. The Middle Shaft, shown on the profile, is simply for working purposes, and may be finally filled up.

Bulkheads about Shafts.—As all the shafts are located in water, from 3 feet to 15 feet in depth, depending upon the state of the tide, bulkheads were necessary, from which to commence operations, and to protect the mouth of the shaft from damage by storm, ice, passing vessels, &c. As shown at Figs. 1 and 2, Plate XLV, these bulkheads consisted substantially of a box 20 feet square inside, formed of oak piles driven 2½ feet apart from centres, and capped by 12″ x 12″ hard-pine sticks, framed at the corners, and drift-bolted to the head of each pile. These caps were further secured at the corners by 12″ x 12″ angle-braces, dovetailed into them. The box was lined inside by 4-inches tongued and grooved sheet-piling, driven to hard bottom, and well spiked to four lines of 4″ x 10″ inside wale pieces. Outside of the piles were two sets of 12″ x 12″ hard pine timbers, spaced four feet apart vertically, and bolted to the piles by 1¼-inch bolts, and tied at the corners of each set by 2″ diagonal rods. The top of this bulkhead was 18 feet above mean low tide, the average rise and fall of tide being ten feet After the iron cylinder had been started within this box, the spaee surrounding the cylinder was compactly filled with puddle clay.

The Iron Cylinders.—To quote from the specifications, "iron cyl-"inders were to be sunk to a depth sufficient to give them a firm bearing, "to ensure the exclusion of tide-water, and to pass through ground "otherwise difficult to excavate." These cylinders are 9 feet 6 inches inside diameter, 1¾ inches thick, and cast in solid sections 5 feet long. The flanges are 5¾ inches wide over all, 2 inches thick, and faced true for a width of 4⅜ inches in from the exterior edge. A groove ½ inch wide, and 1⅜ inches deep, was left between any two abutting cylinders, on the inside, to be caulked with lead if found necessary. The sections were connected by thirty turned bolts, 1⅛ inches diameter, in each joint, and the bottom section in each shaft was provided with a cutting edge, 12 inches deep. The weight of each section was five tons, or one ton to the lineal foot of iron cylinder. The joints were made water tight, by first painting them with thick red lead, and then passing four turns of cotton wicking, dipped in the paint, around the outside line of the bolt holes;

grummets of the same wicking, dipped in paint, were put under the heads and nuts of all the connecting bolts. These joints proved perfectly water tight.

Sinking the Cylinders.—After the bulkheads were completed, pile wharves had to be built adjoining them, upon which to place the hoisting engines, boilers, coal bins, fresh water tanks, &c. To handle the five ton cylinder sections, four stout shear-poles were erected, resting on the corners of the bulkhead, and meeting at the top, over the centre of the proposed shaft, where the ends were secured by rope lashing (Fig. 1, Plate XLV). A hoisting tackle of two triple sheaved "masting blocks," and 4-inch manilla rope was suspended from the apex of these shears. Owing to delay in obtaining the proper kind of clay filling, and to avoid the increased friction as well, the first five cylinder sections in each shaft, were put in place by means of friction clamps, shown at Fig. 2, Plate XLV. These clamps were made of two compound beams of hard pine timber, thrown across the bulkhead, one each side of the cylinder. Each beam was composed of three 12″ x 20″ sticks, the inner one of each beam being carefully fitted to the outside of the cylinder; to increase the friction, four vertical timbers, 12″ x 12″ and four feet long, were bolted to the inside of the beams, as shown on the plan. The clamps were drawn together and made to hold any object between them, by tightening up the nuts on two 2½-inch iron rods that passed through the beams, one each side of the cylinder section. We should here remark, that owing to its resinous nature, hard pine is not well adapted for use in that part of the beam touching the cylinder, white pine is much better, but in our case could not be obtained in time of the required dimensions. The method of operating these friction clamps, was as follows: No. 1 section was first lowered down between the beams, and clamped fast. No. 2 section was next lowered down upon No. 1, the joint made, and the connecting bolts put in and screwed up; with the hoisting tackle still attached to the last section as a "preventer," the two sections were allowed to slip down between the clamp beams in a series of short jumps, by carefully slackening and then tightening the nuts on the clamp rods with a long wrench. A little practice enabled the workmen to keep the mass under perfect control. When No. 2 section occupied the place in the clamps previously held by No, 1, the nuts were screwed up tight, the tackle cast off, and the 3d section bolted on, and lowered in like manner. This process was repeated until the cutting

edge on the first section had reached hard bottom, when the clamps were loosened, and thereafter utilized as guides.

Handling the Material Excavated.—Before the permanent hoisting cages were put in place, the material excavated in sinking the shafts, and in driving a considerable portion of the tunnel as well, was handled by an arrangement shown at Fig. 1, Plate XLV. This was simply an out-haul, working through a single block lashed to the head of a mast planted in the bulkhead ; this mast leaned outward at the top—over the side of the bulkhead. In using this arrangement, the bucket is hoisted a distance above the shaft, fixed by experiment—the out-haul being hooked on to the bucket just as it reaches the mouth of the shaft—and the slack hauled in as the bucket ascends, when the bucket stops, the end of the out-haul is made fast to a cleat on the mast, and the bucket in descending will pass through a curve regulated by the length of the outhaul, until it hangs vertically from the top of the mast, and over the sides of the bulkhead, where it can be dumped. A reversal of this process will bring the bucket again to the top of the shaft, where the out-haul is unhooked, and the bucket lowered to the bottom for refilling.

Sinking West or Inlet Shaft.—All of the foregoing description applies to the three shafts, generally ; we will now confine our remarks to the west shaft, where the depth of the material overlying the rock was greatest, and the difficulty of sinking in like degree increased.

Previous to the letting of the contract, test borings had been made over the line of the tunnel by the City of Boston, and the results exhibited.

Owing to the great expense of so doing, these borings in no place penetrated the rock proper, and, therefore, they failed to give any certain indication of the presence, at each shaft at least, of a stratum of boulders, sand and gravel, lying immediately on the rock, and containing a large body of water. At this west shaft especially, the worst feature shown by the borings, was a sandy clay. The tunnel grade had to be finally lowered 8½ feet below contract grade, to meet this changed condition of affairs.

The material was actually deposited at the west shaft, in about the following sequence : Commencing at the top, mud 3 feet, pure sand 5 feet, and then strata of varying thicknesses of pure tough clay—clay with thin seams of fine sand, and clay intimately mixed with sand. Above

the surface of the solid rock, and meeting the clay and sand deposits, was a stratum 14 feet thick, of large boulders, gravel and very sharp sand, and in this lowermost stratum water to the amount of about 17 000 gallons per hour was found. This water was salt and seemingly in direct communication with the bay above.

In the sand seams struck before the boulder stratum was tapped, brackish water, in maximum quantity not exceeding 200 gallons per hour, was found, but these seams generally drained out and gave little or no trouble. The surface of the solid rock was finally located at the west shaft 123 feet below city datum.

Seven cylinder sections, making 35 lineal feet of iron shafting, were sunk without much trouble, but at this point the frictional resistance of the clay was sufficient to prevent any further sinking of the iron lining by its own weight merely, although the material was excavated below the cutting edge. At this time the surface water was entirely excluded, and the shaft was dry. A dead weight of at first 50 tons was now applied, as follows: On top of the flanges forming the second cylinder joint, or 10 feet from the bottom of the shaft, a platform was built, made of four 12″ x 12″ hard pine sticks, laid in pairs, parallel to each other, leaving a 6-inch space between the two sticks in each pair, and a space of 4 feet between the pairs. These four sticks were accurately fitted to the inside of the cylinder, with as great a bearing surface on the flanges as was possible, holes being made in them for the heads of the cylinder bolts. Two struts, 12″ x 12″ and 4 feet long, were let in between the pairs, and at right angles to them, so as to leave a central opening 4 feet square, opposite the ends of these struts and between the sticks forming the pairs, four wedges were now driven, and the whole structure thus secured in the cylinder. A shaft 4 feet square inside, made of 4-inch plank, on end, and internally braced, was next erected on this platform, and the space outside this box shaft well packed with iron refuse from a puddling furnace. As the cylinder descended, and the friction became greater, this dead weight was increased to a little over 100 tons by putting in a second platform and box higher up in the shaft. Eight heavy screw-jacks were also applied in addition to this weight, on the top flange of the cylinder, reacting against trussed beams, secured by chains to the bulkhead piles.

When the cutting edge of the shaft lining had reached a point 57 feet below city datum, the area of surface then exposed to possible friction

being over 1 800 square feet, all our combined appliances failed to push it any further, and the use of the specified solid iron cylinders had to be discontinued.

Continuation of the Shaft to Rock.—No plan whatever of continuing the shaft after the cylinders were pushed as far as was possible, being specified, the contractor was at liberty to adopt any method that might seem to him most fitting. From the data before him timber was deemed sufficient, and a timber lining was adopted ; the shaft was dry, all water from above excluded, and nothing but clay indicated below him until the rock was reached. Of the wisdom of this decision we will here say nothing, considering that all the known data was derived from deep borings—which more often lead to trouble than exhibit the actual condition of affairs.

The timber shaft was 10 feet square inside, and built of 12″ x 12″ spruce timber, laid skin to skin. As shown at Fig. 4, Plate XLVI., the sticks were cut and laid in alternate lengths of 10 feet and 12 feet, locking over each other at the corners, and to prevent the shorter timbers from being forced inward they abutted against cleats 4″ x 10″ x 16″ well spiked to the long sticks. They were further held in place by the bracing described further on.

The first timber course laid was only 8 feet 10 inches square inside, each succeeding course stepping back 2 inches, until the full dimension of 10 feet square was reached. This was done to give the cutting edge of the iron cylinders a bearing on top of the timber work, at least in the centre of the four sides. Between the top course of the timber work and the iron, a space four inches wide was left in which 4-inch sheet piling was driven out horizontally into the clay and the corners outside the circle thus closed.

The greatest difficulty to be dealt with from the start, and the chief objection against such a compound shaft of iron and wood, was that of properly connecting the two. The corners of a square wooden shaft are the points best adapted for the location of any suspending members, but in our case these corners were outside the cylinder, and consequently, not available. At first four of the cylinder bolts were removed from the bottom joint in the cylinder and replaced by four 1⅛-inch rods, with nuts at the top and lipped plates, catching under the bottom of the second timber course, and secured by 1-inch rag bolts to this course ; below this the hanging was continued by vertical plank spiked to the timbers.

As the shaft increased in length, these 1⅛-inch rods were supplemented by four rods 2 inches in diameter, suspended opposite the centre of each side of the shaft, from heavy iron castings, bolted on top of the second cylinder joint. An iron plate 6″ x ¾″ and 8 feet long was bolted by eight 1-inch bolts, to the middle of each side, and at the top of this plate was an "L" shaped head 8″ x 1½″, through which the 2-inch rod passed, and was there secured by a nut.

This timber shaft was sunk with very little trouble to a point 95 feet below datum, with a maximum quantity of water from the thin sand seams not exceeding 200 gallons per hour. But at the point first mentioned, water suddenly burst in from below at the rate of about 10 000 gallons per hour, driving out the workmen and rapidly filling the shaft, to low tide mark. A steam pump was at once put in place and the shaft again emptied. An examination showed that, while the source was at some point below the bottom of the shaft, the water had in places forced its way up behind the timbering and was entering the shaft in jets through every possible crevice. And what was worse, the main stream was undermining the sides at the bottom, and the jets above were washing the fine sand inside, leaving voids outside the shaft lining. The sides were at once caulked, and the water driven to the bottom, and the 8″ x 8″ bracing, only partly in place, was completed to within four feet of the bottom. The iron cylinder soon commenced to sink, very slowly, showing that the ground surrounding the shaft was in motion clear to the surface. The bulkhead and the adjoining portion of the machinery wharf sank with the cylinder.

The bottom was now a sandy clay, but firm, the water passing to the southwest corner of the shaft as soon as we commenced re-sinking. The material on the east and north sides seemed to drain out and remained quite firm, while on the other sides it soon became very soft, in places semi-fluid. This action increased the strain on the soft sides and tended to throw the timber courses out of the horizontal, the west side sinking more rapidly than the east. As long as the bottom remained firm this inequality of settlement was arrested by "rakers" and "props." All timbering on the soft sides could only be put in place by first carefully poling those sides, but surplus material would escape inside, and increase the pressures. All went well enough under the circumstances until we reached grade—104,

where we suddenly struck a stratum of soft, almost dough-like clay, which we afterwards found was the direct covering of the water bearing stratum of boulders, &c. Into his soft material our rakers, props, &c., easily sank aud became useless as supports, and thereby the strain upon the rods and hanging members on the soft sides was enormously increased, and the west and south 2-inch rods both broke, just above the lower nuts. The immediate cause being the slight bending of the "L" shaped heads of the straps, thus acting as levers on the nuts and ends of the rods. Some of the plank lacing also commenced to give way, and being behind the corner bracing could not be repaired.

Two steam pumps, a No. 8 Blake, and a No. 10 Knowles, were at this time located in the timber portion of the shaft, supported upon platforms, the discharge and steam pipes were clamped to both the iron cylinder and to the sides of the wooden shaft. As soon as the 2-inch rods broke, severing the connection on those sides between the iron and the wood, the lower portion began to settle more rapidly than the cylinder. The effect of this was to break the bottom elbow on the discharge column of our large pump, flooding the lower portion of the shaft to the height of the suction on our reserve pump, the No. 8, at a very critical period. This damage was repaired as soon as possible, and a re-occurrence of the accident prevented by slinging both of our pumps by wire rope to the iron cylinder, and wedging up between pump and platform as the wooden shaft settled.

On sounding through the soft stratum hard bottom was found about 7 feet below the then bottom of the shaft, and as this was very near the point which the boring indicated as rock, we continued sinking. After some tedious and dangerous work, and much trouble and delay from our pumps, which, as is usually the case, were always breaking down just when most needed, we reached the hard bottom only to find it was not ledge rock, but the top of a boulder stratum, of then unknown depth, and the source from whence came all our water, now much increased in quantity. The sand in this deposit was unusually sharp, and would scour through a brass pump lining ¼ inch thick in less than three days, causing further and dangerous delays.

We attempted to sound the boulder stratum by driving iron bars,

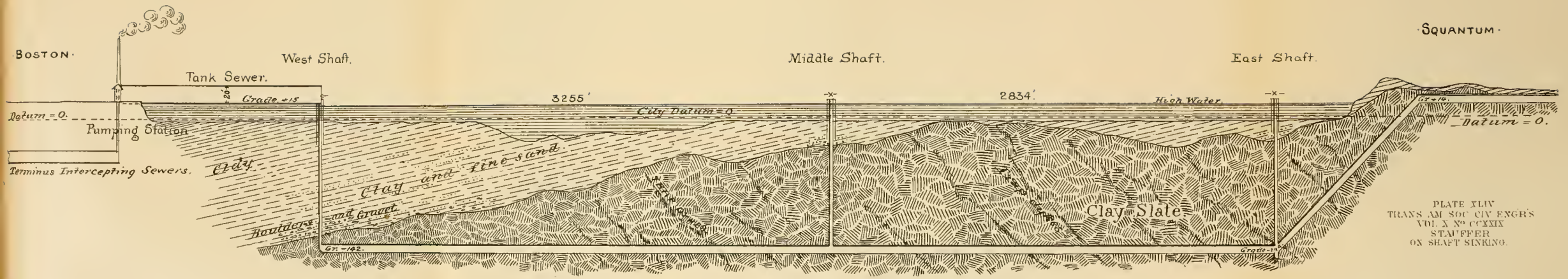

PLATE XLIV
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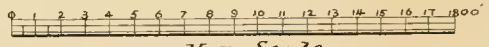
STAUFFER
ON SHAFT SINKING.

Profile Dorchester Bay Tunnel.

Hor. Scale. 600 Ft = 1 inch
Vert. " 100 Ft = 1 "

Vert. Scale.



Hor. Scale.

but failed to get any satisfactory results until we started an artesian boring in a 5-inch pipe, and finally drilled some 8 feet into the rock establishing its actual depth and character.

At this time the bottom portion of our timber shaft was in very bad shape, many timbers broken, the hanging appliances a failure, and the courses very much out of the horizontal. To continue sinking under these conditions was to invite certain disaster. On the other hand, if we stopped sinking, the only alternative to building a new shaft in another location, was the somewhat desperate one of attempting to re-timber the lower 36 feet of the shaft in the face of the moving ground and the consequent pressures. We determined to re-timber without waiting for the ground to settle.

The upper 23 feet of the timber work was still in good condition, the courses almost level, and the lacing intact.. This portion we concluded to leave in, but it had first of all to be securely connected with the iron cylinders, and upon the integrity of this connection all success depended. Iron rods were abandoned in our plans for several reasons, among these the difficulty of attachment, and the fact that in one place, certain obstructions in the shaft prevented a fair lead. Iron wire cables were substituted for rods. Four cables, made by Roebling Bros., were at first used, each cable 6¾ inches in circumference and 22½ feet long from bearing to bearing of the eyes and thimbles spliced into each end. The upper eye was made heart shaped, so that the lashing to be used would not ride and cut under the strain to be put upon it, the lower eye was made to take a 2-inch iron pin, and the splices on each cable were further secured by broad iron clamps bolted over them. On top of the first or lowermost cylinder joint, two hard pine timbers 12″ x 20″ were placed, after having first been accurately fitted to the inside of the cylinder; holes were bored vertically through these sticks, just clearing the cylinder flanges, and passing through these holes, secured above by nuts and 12-inch cast-iron washers, were four eye-bolts made of 2½-inch round iron; two struts were driven between the 12″ x 20″ timbers, to prevent motion.

The lower connection for the cables was more troublesome. At the point selected, two hard pine beams 12″ x 20″ and 12 feet long were inserted in the shaft horizontally, the ends extending out under the sides. These two beams ran in the same direction as the shorter

beams in the cylinder, and were vertically under them. Around each of the 12 feet beams, and directly under the eye-bolts, were four iron stirrups each 6 inches by 1 inch, with two eyes in each stirrup just over the centre of the beam.

Between these eyes the lower end of the cable was inserted and secured by a 2-inch iron pin. The upper eye of each cable was now lashed to its proper eye-bolt by steel wire rope set taut by a purchase connected with the hoisting engine.

The connection being now completed between the iron cylinder and the 26 feet of wood work to be left in place, the workmen commenced replacing the old and crippled timbers, below the hanging beams, with new and level courses—in other words, rebuilding the lower portion of the shaft. As shown on Fig. 1, plate XLVI., a system of timber hanging was at first attempted with 4-inch plank, which plank acted at the same time as struts for the corner braces. This system was soon abandoned. It was all right theoretically, and had it been as easy of application in the shaft as on paper, would no doubt have answered admirably, but in practice it was found impossible, under the circumstances, to keep the inside faces of the timbers sufficiently true to plank against in the manner intended. The same principle was, however, retained by using iron straps 3″ x ⅜″, and four feet long, spiked with 10-inch wrought iron spikes to the timber. These straps were applied in the corners behind the braces, in such manner that each new stick was suspended by two of these straps as soon as it was in place—four feet of the bottom of the shaft was necessarily left unbraced for convenience in working.

A second set of hanging timbers was put in twenty feet below the first, and entirely independent of that set (Fig. 1, Plate XLVI.). In this set each hanging beam was made up of two 12″ x 12″ timbers, placed one on top of the other; the upper one was 12 feet long and passed through the sides of the shaft, the lower one was 10 feet long, and acted as a strut as well. Two 2-inch iron rods, about 10 feet long, each provided with an eye for a 2-inch pin above and a nut below, secured the lower end of each secondary cable to the beams. These rods, in pairs, carried the compound beams between them, the lower ends of each pair of rods passing through a stirrup plate 8″ x 1½″ under the bottom stick, and there secured by nuts. These cables were galvan-

ized iron wire 4½-inches in circumference. They were lashed at the upper end to four 2-inch eye-bolts, which passed through castings bolted on to the second cylinder joint.

This re-timbering was slow and dangerous work, and the greatest care possible in poling could not prevent the escape of some of the outside material into the shaft, the voids thus created, though comparatively slight, kept the ground in constant motion, the settlement being apparent clear to the surface. The first wire cables soon became as taut as harp strings. At first the greatest weight was thrown on the western pair of cables, leaving the east cables comparatively slack ; the strain on the cables was equalized by setting up rakers, extending from the heavy west side to the east end of the main hanging beams. The total settlement of the iron cylinder after the timbering was commenced was just five feet.

The timber shaft was in the above manner successfully carried down to the solid rock, the shaft continued 20 feet into the rock, and the tunnel commenced. About five months after the completion of the timber work the brick lining was commenced. To conform to required lines it was necessary to cut entirely through some of the shaft timbers, and at the centre we found the clay outside generally drained, and in good condition. In the time specified above, the brick work was completed with but little trouble from any motion in the adjoining ground, caution however, was required, and the work was slowly and carefully done.

Pumping out Shafts.—The west and the east shafts were at different times filled with water ; the first was lost by a failure of our boilers, the other by suddenly uncovering an unusually large seam in the rock, through which more water entered the tunnel than could be handled with safety by the two pumps then in place—one of the pumps broke down under the hard work, and the tunnel and shaft filled up. All of our shafts were too small in diameter, when their depth and the quantity of water to be raised through them is considered. This want of shaft room made our method of regaining them somewhat peculiar, and we will relate our experience.

When the eastern shaft was flooded the amount of water to be pumped against was 18 000 gallons per hour, constantly flowing into the tunnel. To handle this quantity of water with safety, under the working conditions, would require a pump of the capacity of a No. 11

Knowles, which measures 9 feet over all, and would require an additional 2½ feet of room at the water end to allow packing, etc. It can be readily seen that such a pump could not be located horizontally, within the iron cylinders, which, as before mentioned, were only 9 feet 6 inches in diameter, a space further reduced by the flanges to 8 feet 10 inches.

To overcome this difficulty we had a special pump built by the Knowles Company, of the bucket and plunger type, double-acting, and working vertically. This pump had a 14-inches steam cylinder, 12-inches plunger, 17-inches bucket, and 24-inches stroke ; its capacity was 11¾ gallons per stroke. (The steam cylinder proved too small for the work to be done, it should have been 16 inches.) The pump was 12 feet long over all, and 3 feet in diameter at the widest part, and with 20 feet of thin wrought-iron suction pipe 10 inches in diameter attached, weighed 7 000 pounds. The steam pipe was 2 inches, the exhaust 3 inches, and the discharge column was 6-inch galvanized-iron spiral pipe in 16 feet lengths, connected by flanges and six ⅝-inch bolts.

On account of its shape this pump was used without platforms built in the shaft. Two heavy beams were thrown across the top of the shaft cylinders, and from these the pump was suspended by a purchase made up of two large triple-sheaved masting blocks, and six parts of 4-inch Manilla rope, connection with the pnmp being made by a strong eye-bolt screwed into the head of the steam cylinder, and by chain slings passing down to the water barrel of the pump. The running end of this purchase passed from the lower block up to a large single block lashed to the top of the four-legged shears, shown at Fig. 1, Plate XLV., and from there down to the wharf, and through a snatch-block to the drum of the hoisting engine. The 6-inch discharge column, and the 2-inch steam pipe, were clamped to separate steel wire ropes, that were secured to the pump below, and thence passed over sheaves lashed to the shears near the top, but as far apart as possible ; from these sheaves each rope went through a snatch-block on the wharf, and then to large cleats, all so arranged that each rope could be paid out steadily, and independently, as the pump was lowered. The exhaust steam passed into the water. To keep the pump from moving laterally when it was at work, oak slides, with clamping screws, were attached to the pump, so that they could be pushed out against the sides of the shaft, and then clamped. The spreading of the blocks to which the discharge and

Fig. 1

To Hoisting Engine.
No. 9. Steel Wire Rope.

2

3

1

Engine Wharf.

12"x12"

High Tide

12"x12"

12"x12"

Low Tide.

ELEV. OF BULKHEAD.
SHOWING "OUT-HAUL" FOR DUMPING MATERIAL
BEFORE CAGE WAS PUT IN.

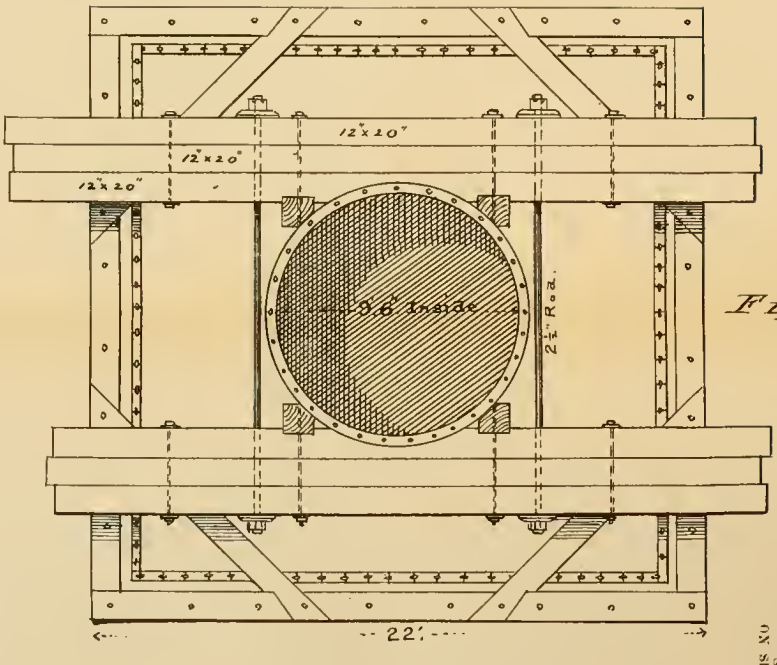
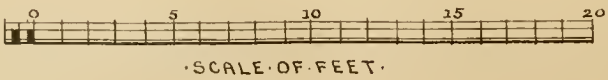


Fig. 2.

PLAN OF BULKHEAD.
SHOWING CYLINDER CLAMPS.



SCALE OF FEET.

PLATE XIV
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ON SHAFT SINKING

steam pipes were suspended was to overcome the twisting tendency in the falls,

The method of operating this pump was as follows : When the water in the shaft had been pumped down as low as possible, the steam was shut off at the boiler, the top elbow and a 10-feet length of horizontal pipe was taken off from the discharge column, and a 16-feet length added to the discharge vertically. The steam pipe was at the same time being disconnected, at a union provided for that purpose just at the top of the shaft, and a new 16-feet length screwed on ; while this was being done on top, another gang of men, stationed on the pump to prevent twisting in lowering, had hauled in the slides mentioned above. All being now ready for a shift, the engineer lowered the pump slowly, and the men stationed at the discharge and steam pipe ropes allowed these pipes to descend with the pump until the top of the newly added section of steam pipe was just opposite the union ; all ropes were at once secured, connection made with the boiler, and the upper discharge elbow and its pipe again bolted in place, the men on the pump adjusted and secured the slides, and all was once more in position, ready to pump out another 16 feet of the shaft. After the men became expert in their several duties the time required to make a shift was about 25 minutes, computing from the stoppage of the pump to the starting again.

But simple as the above may appear, it was only after repeated trials and failures, and considerable experimenting, that the wished for result was attained. At the east shaft we reached the tunnel grade with our suction pipe 166 feet below the top five several times before we could stay there long enough to pump out the 500 lineal feet of tunnel already driven. It should be remembered that the plunger, as we called it, was only an emergency pump intended to empty the shaft and tunnel preparatory to setting up a large permanent pump of the horizontal type in the tunnel. The vertical pump was troublesome to handle, took up much room with its ropes and pipes, and was difficult to pack.

The steam connection was the most troublesome feature. When the pump was in action there was a very considerable vertical motion due to the elasticity of the fall ropes. This was especially the case when we neared the bottom of the shaft, and a rigid steam connection was consequently impossible. After trying a jointed steam pipe, without

success, we made use of a 6-ply gum and canvas steam hose, 6 feet long, placed between the steam pipe and the steam cylinder on the pump, but, under the steam pressure carried, 100 pounds at the boiler, this hose burst in a few hours ; 10-ply canvas and pure gum was next tried, but even this would sometimes fail, by the intense heat softening the gum and thus allowing the hose to blow off of the iron nipples in the end, in spite of grooves and broad iron clamps, intended to prevent any such accident.

The radiation from the steam pipes, and the ascending steam, caused by water falling on the hot cylinder and pipes, made the temperature in the shaft almost unbearable. This, and the entire want of ventilation in the deep and narrow hole, caused great physical suffering among the men whose duties called them inside, especially when this experience was varied by the bursting of a 2-inch steam hose in the face of the pumpman. To the pluck and endurance of these faithful workmen all success was really due. This 166 feet of shaft was finally pumped out in a little less than nine hours. Having, we hope, given a sufficiently detailed description of how we got into a scrape at the west shaft, and how we finally got out of it, we can now look back and see where we made our mistakes.

First of all, it should have been taken as granted that water was to be met with in abundance, under the circumstances, as we neared the rock. All indications to the contrary, obtained from borings, should have been disregarded. Had this been done, in the opinion of the writer, it would have been ill-advised to have used any form of compound shaft, partly wood and partly iron. The iron cylinders should have been continued to the rock, by using iron rings of reduced height, and cut into four or more segments, put into place at the bottom of the shaft, as soon as the friction prevented the further descent of solid cylinder sections, and the surface water was excluded. The advantages would have been many as compared with the attempt to hang a square wooden shaft to an iron cylinder, the vertical connection would have been continuous and abundantly strong, and the entire shaft could have been made water-tight by caulking the joints with dry pine wedges, or otherwise. And with rings not more than 2½ feet in height, any soft ground could have been passed by a proper system of poling.

It is true that some hanging appliance similar to that finally used might have been at first put into a timber shaft, had the possibility of

meeting water been duly considered by all parties concerned, but the experiment, we think, would have been a dangerous one, as compared with a continuous iron cylinder, and all things considered, it would not have been as economical as iron.

NOTE.—The Dorchester Bay Tunnel was commenced in January, 1880, and at this date some 4 600 feet of the tunnel are driven. The contract was let to Mr. R. A. Malone, of Pennsylvania ; the writer was engineer for the contractor.

We cannot, in justice, omit the mention of our personal indebtedness to Michael Nolan, who superintended the retimbering of the west shaft, and to William Reardon, the rigger, who put into place our hanging-up appliances. To the pluck, endurance, and practical knowledge of these two men, very much of the success was due.

PLATE XLVI
TRANS. AM. SOC. CIV. ENG'RS
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STAUFFER
ON SHAFT SINKING

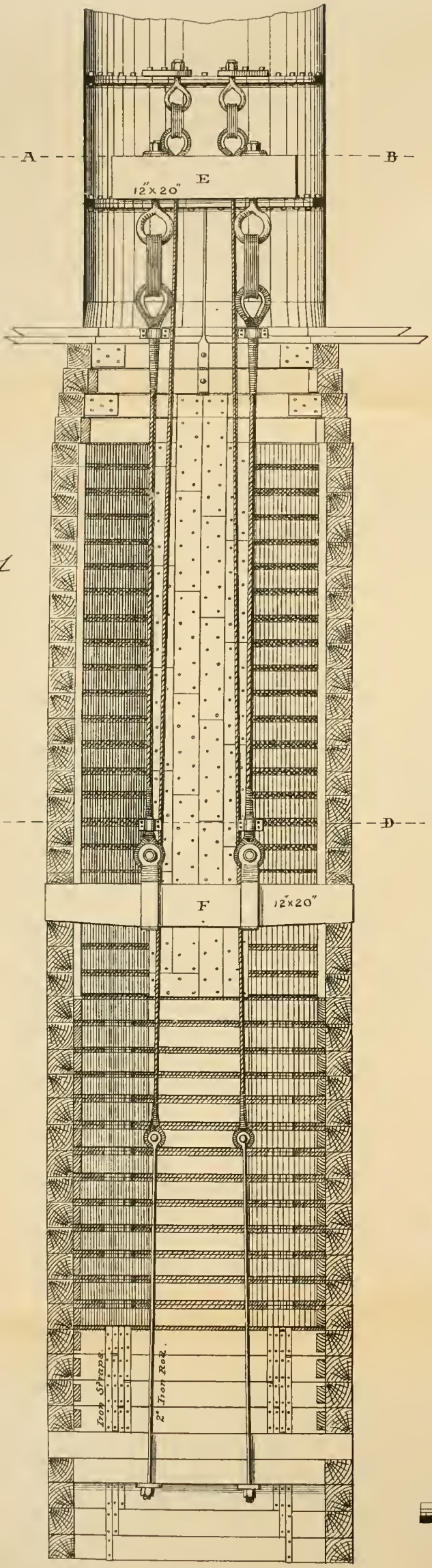
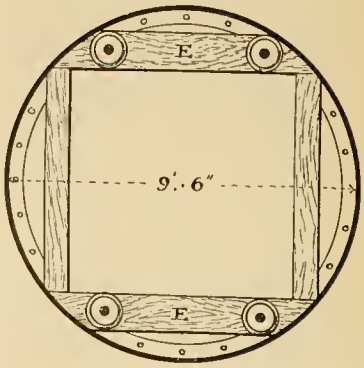


Fig. 1

Vert. Section of Shaft.



Section on A.B.

Fig. 2.

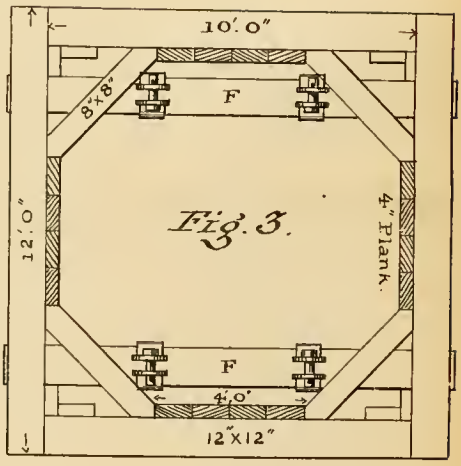
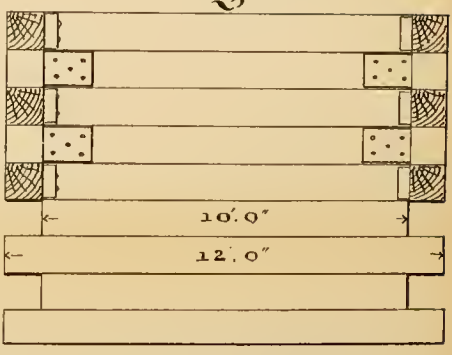


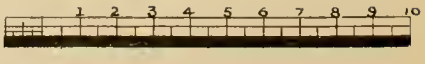
Fig. 3.

Section on C.D.

Fig. 4



Shaft Framing.



Scale of Feet.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXXX.

(Vol. X.—November, 1881.)

SEWERAGE SYSTEMS.

By RUDOLPH HERING, Member A. S. C. E.

READ AT THE 13TH ANNUAL CONVENTION, JUNE 15TH, 1881.

With Discussion by CHARLES E. FOWLER, Member A. S. C. E.

The writer desires to offer the Society some remarks on sewerage systems, drawn partly from a recent examination of the most interesting of such works in Europe, and partly from his own experience in this branch of engineering.

There seems to be still a considerable amount of uncertainty regarding the merits of different systems, if we judge from the continued polemics among professional men in Europe, and recent discussions in our own country.

But, as more experience is being gained, it is also noticeable that opinions are converging, and the direction in which the best solution may be found, is becoming more distinctly indicated.

To state in what the writer believes this direction to consist, is the object of this paper.

It may be well at first to direct attention to a few difficulties in the way of arriving at an impartial judgment of the matter.

In the first place, it can be noticed that the habitual engagement of the mind in certain directions of thought, will more or less tend towards a one-sided view of all outside questions, and, in thus influencing opinions, cause what might be termed a professional bias.

We can observe, in Europe, that chemists, agriculturists, and hygienists are, as a rule, prominently conspicuous in the opposition to the water-carriage system. They point to the injurious effects of soil contamination by sewers, of the gases and germs emanating from them, of river pollution and various dangers expected to arise from sewage farming, as well as to the value, as manure, of undiluted excreta, and the national importance of preventing its waste, all of which comes more or less within the special range of their professions.

On the other hand, we can notice that municipal engineers who, in addition to the sewage problem, find themselves confronted by such as the removal of storm and sub-soil water, of house refuse, the construction and cleaning of streets, the supply of water to dwellings, and its subsequent removal, and finally, by the very weighty necessity of exercising the utmost economy of expenditure in their works, are quite generally in favor of water carriage.

What seems so apparent regarding this system in its general features, may also be expected to affect the views regarding its special applications. We are, therefore, not surprised to discover a division of opinion concerning the relative superiority of the "separate" and "combined" systems, and, lastly, to find that even some details of each, form points of dispute.

Each person judges matters from his own sphere of working, and it seems that, by considering this unconscious bias and eliminating its tendency to exaggerate insignificant facts, both *pro* and *con*, and, on the other hand, by fully realizing the most essential features, we may advance a step towards truer conclusions.

For instance, the engineer ought to pay greater attention to the sani-

tary demands upon his works, and endeavor first of all to completely satisfy them, because they are the prime requirement of the system. And his opponents ought to inquire more carefully into the technical nature and necessity of correlative city requirements and works, and also into the question of municipal economy.

Our opinions on the relative merits of designs are also sometimes misguided by ignorance of the local history of existing works. It often occurs that financial considerations have caused certain features, be it with reference to a new use for old works, or to a peculiar use for new works, wh ch outsiders are apt to misinterpret.

As the physical features greatly influence designs, erroneous opinions can also easily arise from an incomplete knowledge of them.

Even the customs of the people can materially influence designs, and certain features may be acceptable in one locality and strenuously objected to in others. For this reason the system of dry removal, as practiced in some European towns where water-closets are not used, and where the exchange of casks is done under very strict surveillance, is not objectionable from a sanitary point of view, whereas in our own towns it would probably become a great nuisance.

Finally, there is a difficulty in rightly judging the works of a city, in the fact that old practices and laws are more or less hard to change. When certain customs, either in the designing or the execution of the works have prevailed for some time, they will generally be adhered to, unless absolutely faulty, and novel matters of any consequence will be adapted to the old works.

The writer thought it pertinent to mention these various points, partly because they seem to have been a prominent cause for the variety of opinions, and partly because he felt it necessary to keep them in mind when comparing the various methods and works, in order to be better able to appreciate their relative value, and to judge of their applicability in other localities.

General Systems.

We will now inquire into the several methods of removing offal and waste water from towns, and then endeavor to trace their relative merits in order to discover in what direction an ultimate agreement may be found.

Each system must be examined under two aspects. The first in importance is its sanitary value. The second is its cost. While the former should be absolute, demanding a satisfactory standard in every case, the latter is relative, depending on a great variety of conditions.

All systems should, therefore, first answer the hygienic requirement of preventing decomposition of organic matter, under conditions which permit unhealthful influences. After this object has been satisfactorily attained, the only other point of comparison is confined to the expense of construction and maintenance.

In general, two methods have been proposed to satisfy the sanitary stipulations, the so-called "dry removal" and "water-carriage." The former accomplishes its object either by temporary storage, with frequent removal, before decomposition can be rendered injurious (casks and pails), and the latter by immediate and continuous self-removal (sewerage). Let us briefly examine into the nature and applicability of each of these methods.

I.—Temporary Storage and Periodical Removal.

We have, under this head, a variety of ways in which excreta are collected and removed.

Among them, the most common in our own cities, is the storage in cesspools under or near the dwellings. The fact that these appliances require the least outlay of money is the cause of their extended use. But, because they do not comply with the sanitary requirements, by permitting decomposition near the houses, the penetration of foul liquids into the soil under them and the ready escape of gases which carry injurious germs into the air around us, their use should be strenuously opposed in all densely populated districts or where drinking water is obtained from wells which might be polluted by them. In many European cities cesspools are strictly prohibited.

A much better contrivance, and one which is supported by many sanitarians, is the storage in casks and pails, with a frequent removal at intervals varying from one to six days. This method is very common in Europe, and has been given the preference over all others by a number of prominent men. An inspection of the best examples in cities like Paris, Rochdale and Birmingham, Heidelberg, Stuttgart and Zürich, is convincing that they can, if properly designed and managed, answer

all sanitary requirements, and indeed their advocates are found to be principally among hygienists and physicians.

The applicability of casks and pails is not limited by any topographical but by social conditions. They become impracticable wherever the use of water-closets is the general custom, on account of the large additional amount of water discharged into them.

In Paris they use for about one-fifth of the population the so-called "*fosses filtres*" which are casks retaining only the solids and allowing the fluids to drain off into the sewers. They are mainly introduced to satisfy popular prejudice against fæces entering the sewers, which is presumed to create very objectionable exhalations. These "*fosses*" should be considered, as they undoubtedly are, a transitional contrivance towards the introduction of complete water carriage.

It may be questioned whether the casks and pails will ever meet with the same favor in our country as in the mentioned towns of Europe. For, in the first place, we have not the same rigid regulative conditions, and could not depend as well on the faithful and proper exchange of the pails, in short, on a management of this system which would make it much superior to well-built common privies. Then, we consider a liberal supply of water one of the first requisites of a growing town, and having this, the waste water and the gradual introduction of water-closets generally makes sewers preferable.

However, there may be cases where the pail system can be advantageous. But it will be limited to small towns, on account of the expense of cartage, and to localities which are expensive to sewer.

Finally, we must mention the appliances which, from a sanitary point of view, are the best under this head, namely, those where decomposition is retarded or arrested by the addition of disinfectants.

Two means can be employed, either preventing decomposition by absorption of the moisture, or conversion of the dangerous compounds into uninjurious ones. The former is accomplished by dry earth, charcoal, etc., the latter by carbolic acid, chloride of calcium, creosote, etc. To render disinfection efficient, it is necessary to add the material in sufficient quantities after every evacuation.

However good this method is, its expense in supplying and removing the additional materials precludes its extended application.

The well-known dry-earth closet is one of the best contrivances in use, because it is effectual in its object without being too costly. It can be

recommended for small country towns and isolated buildings, without a regular water supply or sewerage, and where the supply of fresh earth and the disposal of the resulting manure can be properly attended to.

II.—Immediate and Continuous Self-removal.

This is accomplished by means of "water carriage" or sewerage proper, and is made possible by the fact, that the usual amount of fluid waste discharged from the dwellings, which are furnished with a regular supply of water, is about sufficient to float or flush away the solid waste matter excepting of course garbage and ashes.

A continuous system of underground channels leading from the dwellings to a place of final disposal ought therefore to completely remove, with proper gradients, etc., all substances of the above nature, which by their retention might produce injurious effects. Yet, in point of fact, this has often not been accomplished, and the opposition to sewerage, especially from those who are mostly concerned about the sanitary question, has therefore been very strong.

This unsatisfactory condition of many sewerage works has caused still other disagreements. While admitting that the principle of water carriage is good, opinions differ as to the designs by which it is to be accomplished, whether the sewers shall also receive and discharge storm waters, or shall be limited to convey sewage alone, the former being termed the "combined"; and the latter the "separate" system.

Even the latter is represented in different forms. We have the "ordinary" separate system which is built on the same general principles as the "combined," excepting that the size of the pipes is proportioned for sewage alone, and that no provision is needed for the entrance or discharge of rain water, which is led off either over the surface, or in separate channels. It is much used in England, and has lately been adopted in Memphis, Tenn.

Then we have the Liernur system, which is used in several cities in Holland. It consists of iron sewers of a uniform diameter of 5 inches, into and through which the sewage is drawn to a central station by means of a vacuum created in them by an air pump. At this point it flows into barges and is taken to neighboring farms.

The composition of the sewage thus provided for, is different from that in other towns, as it consists solely of excreta and chamber slops,

and has therefore greater agricultural value. Water-closets are not objected to, although their use is discouraged.

A second system of pipes, similar to ordinary sewers, is proposed for removing the waste water from kitchens and factories, as well as the subsoil and rain water. This part of the Liernur system has never yet been built. It is easily seen that it alone could differ very little in design, extent, and therefore cost, from the combined system. For, as the quality of the supposed contents would nearly equal that of the present Paris sewage, which contains practically no fæces, and only a small proportion of urine, they would be nearly as foul, and the Paris sewage is sufficiently strong to require the same treatment as that from water-closeted towns. Wherever the Liernur system has been carried out, this underground house and rain water conveyance has not been very much needed, for topographical reasons. The expense, therefore, as usually given applies simply to the pneumatic system, or the removal of excrementitious matter alone.

The details of the works are ingenious, and their operation is satisfactory from a sanitary point of view. The closets, where the use of water is restricted, are not as clean as elsewhere, but otherwise no complaint can be made, as all excreta are quickly removed in pipes, from which no gases and germs can escape, and are collected at the out fall in a more valuable condition for agriculture than ordinary sewage can be.

The expense of Liernur's system, however, is to be its great objection. Besides the sewerage necessary for the rain and house-water, which alone would cost about as much as a regular "combined" system with its street inlets, man-holes and junctions, there are iron pipes, with reservoirs, chambers and valves, in every street. And the maintenance itself is expensive, for instead of using gravity to transport the fluid, this is done by means of a vacuum produced by artificial power.

The applicability of the system is limited to localities where the use of water-closets can be restricted, and where a purification of sewage is necessary. Enough experience is gained to know that it cannot compete with the ordinary gravitating systems on account of its cost, except, perhaps, in extraordinary cases, where the latter cannot be employed.

Another variation of the separate system is being introduced by Mr. Shone in England.

Its peculiar feature is the Shone Ejector, a patented automatic pump worked by compressed air, supplied from a central station. Its main advantage is to obviate the necessity of deep cuttings, by placing an ejector wherever this would be necessary, and raising the sewage to any convenient height, from which it can again flow by gravity. The automatic action of the pumps and the facility with which any number of them can be operated from one compressor may recommend it for certain conditions.

In low flat districts, where deep excavations may be very troublesome, perhaps through quicksand or water, a raising of a few feet now and then, could keep the sewer above the annoying strata. Also, in undulating territory, where the sewage is to be conveyed across several ridges, it may be preferred.

As Shone's system is too new to permit reliable conclusions, and Liernur's has very limited advantages, if any, over the ordinary "separate" system, we shall confine ourselves in the following to the latter and the "combined."

The objections against water-carriage have mainly been: A pollution of the soil around the sewers, the incomplete removal of the solids, which often makes the sewer an "elongated cesspool," the consequent dispersion of gases and germs from them through openings into the streets and houses, the pollution of the rivers by the discharge of filth into them, and the pollution of the air from sewage-farms.

The main points usually given in favor of water-carriage are: A greater cleanliness in and around the dwellings by the use of water-closets and the immediate underground removal of all waste water, a greater certainty in its removal on account of being automatic instead of dependent on human aid, and a greater economy in the case of populous districts.

From general observation, the superiority of water-carriage in cities seems evident, for its adoption is rapidly progressing even in towns where it has once been much objected to. But also a close examination of the executed systems shows them to be superior, and that sanitary objections are only founded on works that are imperfectly planned, built or managed.

The pollution of the soil has only been noticed where sewers were carelessly built; the deposit of filth in them is caused by improper grade, shape, or maintenance; the pollution of rivers arises only when

the sewage is improperly, or not at all, purified ; and the pollution of the air from sewage farms is found, if the latter are well managed, to be without any dangerous effects.

In our own country we have recognized the superiority of water-carriage over dry removal, at least from the point of view of being cheaper, and, as far as the dwellings are concerned, also cleaner, and it does not seem that the latter will ever be introduced to any extent. The only dispute which may arise among us will be with reference to the relative value of the several systems of water-carriage itself.

We will now give a glance at some of their guiding principles, for we think that the insufficient attention given to them has often caused the failure to satisfy sanitary or engineering demands, and, therefore, quite naturally has given rise to the attacks upon the entire system.

The general design can be materially effected by the manner in which the sewage is to be ultimately disposed of, and by topographical features of the site of the town. Different types are therefore found to suit different conditions.

When discharged into a comparatively large body of water, either river, estuary, or sea, purification can be ignored, as far as the sanitary question is concerned.

The only object to be sought is to prevent the solid particles of sewage from lodging along the shores. It can be accomplished in running water by an outlet near the main current and in tidal water by a discharge so far below the town that it cannot return, or by a temporary storage and discharge at or after high water.

It makes no difference in this respect whether the sewage is brought to the outfall from a separate or a combined system. Either is alike applicable from a sanitary point of view. The cost alone will govern their relative advantage when the sewage is thus discharged.

When, however, purification is required, the size of the river, the position of the town, its topographical features and existing works, will be factors in determining the value of the system to be preferred.

The use of the "combined" makes it necessary to intercept the sewage proper, and to lead it alone to the point where it is to be purified. The interception, however, cannot always be complete. During rains the sewage is more or less diluted, possibly not differing at all from that which is not intercepted and flows into the streams.

If the diluted sewage during storms cannot be allowed to run into the streams, then the separate system becomes preferable for health, and for economy also, when purification of the diluted sewage is costly on account of difficulties connected with the locality.

But if the occasional discharge of diluted sewage can be permitted in the rivers, and this will mostly be the case because it differs little, if at all, from the surface washings of towns and fields, then the combined system is to be preferred on grounds of economy, unless the question must be decided on other points.

Existing sewers, which can be used for rain-water, but not for sewage, on account of improper design or location, may cause the separate system to be cheaper, as comparatively small pipes are required for sewage alone.

When the town lies along the banks of a large body of water, or is stretched out along the foot of a steep slope, having in both cases very short drainage areas, from which the storm water can readily run off on the surface, it will be more economical to build sewers for sewage alone.

Thus it is seen that different features of the locality will be best served by different systems, provided they can equally well satisfy the sanitary demands.

This proviso must, therefore, be first determined, and on it there is as yet no unanimity of opinion. The filthy and unsatisfactory condition of many combined systems have been the cause of a belief that the principle is at fault; and greater satisfaction is expected from a more universal application of the separate system.

Our recent inspection of works on both plans has fully satisfied us that no decided preference can be given to either one, when equal care is applied to design, construction and maintenance.

The best works existing at present belong to the combined system, which are the sewerage of Frankfort, Hamburg, and Danzig, the main drainage of London, and parts of the works in other English cities.

The separate system, which has been advocated since 1851, when it was applied in Tottenham, has since been used in Oxford, Reading and other small towns. An inspection shows, also, their sanitary condition to be good, but no better than that of the before mentioned works.

The bad condition of many of our own systems can, therefore, hardly be due to the fault of a principle, but to faulty design or construction, or insufficient care in their maintenance.

We shall now allude to various principles, the neglect of which has been observed to give rise to these defects. When sewers are too small to be entered, they should have man-holes at every point of lateral deviation, and man-holes or lamp-holes at every change of gradient, the entire change taking place in the holes themselves by means of short curves. Between these points the pipes must be laid in perfectly straight lines, with additional man or lamp-holes, at distances not exceeding 300 feet, so that the whole system can be examined at any time throughout its entire length, without breaking open the street.

The importance of this principle, which was first recognized and consistently applied by Robert Rawlinson, has been fully demonstrated by long experience. One of its chief merits lies in the fact that it is based on actual experience, instead of pure theoretical reasoning. Numerous failures have been and are still traced to its being neglected. The instances are many when it was thought impossible that small pipes, with all their entrances guarded and screened, should ever get choked, and yet it is a frequent occurence, in spite of the strictest regulation and care.

Another principle of alignment is gained from the fact that a sewer of x times the capacity will not cost x times as much money. It will be economical to lead as many sewers together into mains as possible, instead of keeping the sizes more equal.

With the same lengths of sewers, not only a reduction of cost can thus be gained, but also the concomitant advantage of having better gradients for the smaller sewers or branches, where they are most needed, which contributes to the sanitary efficiency of the system.

Still another point presents itself in the alignment which should be kept in mind. A great velocity of the sewage, when changed to a slight velocity, causes a subsidence and deposit, which is one of the first things to guard against in a perfect system of sewers.

It is, therefore, important to give the sewers a greater length, *i. e.*, less grade on the sloping grounds, in order to equalize the velocity with that in flatter grounds as much as possible. This does not necessarily imply a greater length of sewers for the town, but only a different distribution.

Finally, we will mention a system of alignment used by Mr. Lindley in Frankfort and elsewhere, by which the troublesome dead ends of the branch sewers are avoided. Instead of allowing the latter to terminate

abruptly, he unites them with the sewers of the next higher section. By this means it is possible to flush the branches, whenever necessary, with a copious flow from a main above. A disadvantage accompanying this system is a loss of grade to the former, but the possibility of giving a powerful flush at any moment will mostly outweigh it, when the gradients become flat. The summits of the system are by this method reduced to a minimum and the water for flushing them is obtained, in Frankfort, for instance, from the subsoil, and is allowed to accumulate in a porous brick reservoir.

Although this method of alignment is rather expensive, especially when consistently carried through, it may often proportionately reduce the cost of maintenance. The excellent condition of the Frankfort sewers is greatly due to this facility for thorough flushing. Fields' flush tanks have recently been elsewhere introduced to overcome the same trouble of dead ends, partially with good effects.

All of these points apply more or less to both the combined and separate systems.

The gradients of sewers next give occasion for a few suggestions.

As the grade which is necessary to give proper velocity to the ordinary flow of sewage must answer other requirements than the grade necessary to remove storm water, a distinction between these should be made.

In the former case it is limited by a minimum which is sufficient to move the usual sewage fast enough to prevent deposit, unless other means of assisting its removal must be resorted to, as, for instance, in very level districts.

The grade of the sewer invert can usually be considered as equal to the one causing the velocity, although there are cases, as in Hamburg and Westham, near London, where the former is a dead level, in order to allow the sewage to flow in either direction as may be required, and when the velocity must be determined from the hydraulic gradient.

The storm water discharge which regulates the size of the sewer, should have its velocity calculated from the hydraulic gradient. This is especially necessary when the outlet is partially or entirely below high water level of the river.

By not considering this distinction the capacity of sewers during storms has often been materially impaired, although intended to effectually discharge the water. And it has given cause for a foul condition

due to slack water, which was laid to the fact of attempting to lead storm water and sewage into the same channels instead of to an improper design of the works.

The size of the sewers, after the grade had been considered, depends on the quantity of water to be conveyed, and causes the main distinguishing feature between the two systems.

Where sewage alone enters, the size is determined from the maximum flow per second which is likely to occur at any hour or day. It will therefore vary with the density of population.

Where storm water is to be led into the same sewers, the amount of sewage itself becomes so insignificant that the size can be regulated by the former alone. The amount of storm water for which allowance should be made is not yet a settled question. There has often been trouble from this cause, for when too small, the sewers are likely to cause flooding, and when too large, a deposit and resulting decomposition. A satisfactory range of experience is yet to be compiled on this point.

Self registering rain gauges, stationed at near intervals over a comparatively large drainage area, together with a gauging of the storm water discharged by the sewers, can alone furnish a reliable guide. By thus observing the extent, intensity and movements of storms, and their corresponding effects in the sewers at different seasons from different slopes, paved areas, lawns, &c., a scientific proportioning of sewers would be more possible than now.

In the meantime, the next best information is very acceptable. We have recently obtained an empirical formula from Mr. Burkli-Ziegler, which may do good service as a guide where sufficiently extensive observations have not yet been made.

Having collected data on the intensity of some heavy storms, and the corresponding discharge of sewers in Zurich, he collected whatever other information he could obtain from other European localities, and found the following relation :

$$q = c\,r\sqrt[4]{\frac{s}{a}}$$

wherein,

q=water-reaching sewer in cubic feet per acre per second.

r=average intensity of rain during heaviest fall in cubic feet per acre per second.

s=general grade of drainage area in feet per thousand.

a=area drained, in acres.

c=coefficient, for average cases=.625

The range of observations was limited to comparatively small areas, and included some of the heaviest known rainfalls. The slopes of the areas extended to 10 feet per hundred. He proposes the coëff. c=.625 (for English measure), as it covers most of the observations, but for paved streets in London finds it to be .75, and for suburbs with lawns and unpaved streets, as small as .31. The values of r which he recommends for Switzerland and Central Europe are an average intensity of $1\frac{3}{4}''$ to $2\frac{3}{4}''$ per hour, depending on how far provision is deemed expedient for extraordinary storms.

The principle which the formula embodies is to give to the fraction of the rainfall which enters sewers a decreasing proportion per acre per second for an increasing size of the drainage area, a fact which in general has been long recognized.

By an intelligent use of this formula, somewhat more rational sizes can be obtained, than by the rule of three, which is yet so commonly applied to areas covering thousands of acres, but which is only reasonable when the areas are very small. In the latter case when the areas are less than say 20 acres, a simple proportion is probably better than the above formula; *i. e.*, the rain-water entering the sewer will be about in a direct proportion to the area from which it flows off.

In connection with this another point must be mentioned. The longer we can keep the rain-water flowing on the streets, the less provision is necessary for it under ground. Therefore, it is advisable to prevent its entrance into sewers as long as practicable without flooding streets, endangering basements, or otherwise causing trouble.

Whether gutters, open or covered, can be allowed to cross the streets is a question for each municipality to determine. They are decidedly objectionable, however, in main streets, and in large cities the tendency has been to abolish them wherever they existed. When gutters receive nothing but rain-water, the latter, when it comes from a few blocks only, can generally be led across the street junctions of a good and smooth modern pavement without any trouble. Especially near the water-shed line of the drainage area good use can be made of this consideration, by a proportionate reduction in the size of the pipes.

The foregoing remarks on the size of sewers for the combined system, show that it may often be safely reduced, especially in the lower parts of large drainage areas, which not only saves expense but improves the sanitary condition, by getting a more rapid flow and less exposure of surface for the same quantity of sewage.

We have now to inquire into the main influences effecting the velocity other than the grade which has just been considered.

An acceleration produced by the water entering the many connections will be slight, if at all perceptible; the retarding influences, however, deserve very careful inquiry, as they greatly affect the sanitary condition and perfect working of the system. Whatever enters a sewer should be steadily carried along to the outfall without the retention of a single particle.

Connections should therefore be placed so that the entering water has a direction as near as practicable to that of the sewer and a velocity at least equal to it.

Junctions of sewers should be made either with as large a radius as possible, when they are capable of being entered, or, with an extra fall to counteract the corresponding loss of head, as their radius diminishes, which latter is the only proper expedient for pipe sewers. In order to produce no backwater, the smaller sewers should deliver their daily maximum discharge at least at the same elevation as the larger ones.

A most important influence on the velocity of the sewage is found in the degree of roughness of the sewer's perimeter. By a smooth surface not only a greater velocity is gained, but an adhesion of organic matter is greatly prevented, causing what in Germany is known as the "*siel-haut*,"* and which is claimed to be the greatest impediment in the way of making water carriage successful, from a sanitary point of view. Therefore, the smoother and more regular the surface, the better. Glazed pipes are good for this reason when their joints are even and do not project. Concrete sewers, as built in Paris and Vienna, where they are continuously moulded in the trench against planed iron sheeting, are excellent. Brickwork should be built of the best bricks, carefully jointed; and rough brick or stone work ought not to be permitted, as through it most of the trouble laid to the combined system, as such, has been caused.

* Slimy coating along the sides of sewers.

The section of sewers offers the following points for comment. The proper conveyance of the daily flow should be in a circular or semicircular channel, just large enough to hold it, because this form gives to a certain amount of fluid its greatest flushing power, the importance of which for the heterogeneous body of sewage cannot be overestimated.

The section for sewers receiving nothing but sewage, should therefore be circular, assuming them to run full or half full.

When rain-water is to be occasionally admitted, the same semicircular section of the same size, which was found best for the conveyance of a certain amount of sewage, in the first case, should be preserved also in this one. To convey the rain-water, the necessary space should be provided for, above this channel required for the sewage, but without materially changing its form or size. An egg-shaped section is thus obtained, together with the elements which designate its proportions. The invert should become more pointed as the relation between the quantity of daily sewage and maximum rain-water becomes greater.

Many of the sections commonly used are made too flat in the invert and therefore give but a slight advantage over the circular form. The latter, although still used at some places, is quite inappropriate for the combined system, because it permits the daily flow to spread out into a shallow stream, reducing its velocity and by a continual variation of level, causing deposits along the edges.

These results are often quoted as inherent defects of sewers which receive such differing quantities as sewage and rain-water in the same channels. Yet it will be seen, that if the sewage itself in both systems, is led off through sections substantially alike in shape and size, the effects cannot be very different. Only after storms, when the floating particles may, while the water subsides, strike and permanently adhere to the sides, a troublesome effect can be caused. But our inspection showed clearly that when the surface is smooth, this adhesion is practically insignificant to sight, and was confirmed by the slight odor always perceptible in concrete or other smooth sewers as against those with rough perimeters.

The effects of flushing in the two systems will not differ much, if the inverts are alike. A small quantity of water as discharged from flush tanks or chambers at the heads of branches, will have about the same cleansing effect in either case. In the separate system, *i. e.*, in small

pipes, an advantage is gained by being able to flush under a head, and thus obtain for a smaller quantity of water a greater velocity. In the combined, an advantage is had from the periodical flushing by storm water, which is very effectual, and, in fact, is the only manner by which sewers get cleaned in many of our cities.

In wrongly designed sewers this rain-water flushing is not sufficient to cleanse them, and even in rightly designed sewers, it cannot be solely depended on, and it will be necesary at times to clean sewers from substances too large or heavy to be removed by flushing water. It is an indisputable fact that such obstructing bodies will get in, although carefully provided against, and there must be some ready means to take them out. In large sewers removal by hand is the quickest and cheapest way. Where they cannot be entered, it is necessary to push or pull brushes or other implements through, or to let a wooden ball of slightly less diameter float through them, as is done in some English towns, and in the large syphon under the Seine, at Paris. Small sewers, therefore, require to be accessible at frequent intervals, to permit this cleaning, and avoid a breaking up of the street and sewer.

As a large proportion of the sewers of a combined system can generally be entered, and thus allow the unavoidable obstructions to be more readily removed, it deserves preference in the direction of maintenance.

The question of ventilation also offers some points of comparison.

Generally speaking, the exhalations from sewage will vary with the bulk and surface exposed to the air, but not with the quantity of air above it. The large quantity of the latter in the combined sewer, therefore, does not necessarily contain more impurities, as has been asserted, than the small amount of air in the separate sewer, other things being equal.

It is true that the former has more decomposing matter adhering to its sides, but it is also true that it has a much larger proportion of air to dilute the resulting gases. As a matter of fact, the odor emitted from small sewers is more offensive, because more concentrated, than the odor in large sewers, both being in good order.

The degree of foulness of the sewage depends on its age, on the rapidity with which it is discharged, and on the proper construction of the works generally. The dangerous condition of the air, *i. e.*, the amount of impurities contained in it, will, therefore, likewise depend on these circumstances, rather than on its relative volume in the sewer.

As a free circulation of air is always necessary, ready means of egress and ingress should be provided, not only to remove the gases and germs, but to yield to the fluctuations of the sewage. In well built and maintained sewers, open gratings in the roadway have not been found objectionable. In some cities, as Paris, Hamburg and Leeds, the rain-water inlets along the sidewalks are without traps, and permit a free communication with the outside air. In a number of towns in Germany the circulation is also facilitated by the main house drain pipes, which are untrapped and carried above the roof. Special appliances for ventilation, as chimneys, etc., with natural or artificial draughts, which are found to act at best for a very short distance, have more or less been abandoned for the idea that frequent small openings in the streets are more efficient and less expensive, especially in connection with ventilation obtained through house drains.

The objections to this manner of ventilating the sewers come mainly from the advocates of the dry removal, or the Liernur system, in both of which sewer air cannot exist in the street. Yet their objections are only substantiated by works that are not properly built or maintained, and, on the other hand, the exhalations from the Liernur closet, when the use of water is limited, and from the casks and pails in the dwellings themselves, are at least as objectionable, if not more so.

If ventilation can be carried out as stated, it will, therfore, be of little difference to which system the method is applied, and the purity of the escaping air will depend far more on the way in which either is designed or kept in good order.

A few more points remain to be considered.

Where it becomes necessary to prevent storm water from running through the streets and over the crossings in closely built up districts, it must be carried away in underground channels. In the separate and combined systems, equally, provision must be made. In the former case separate channels are required, for which old and otherwise useless sewers may be used, or when newly built they can be only slightly below the surface. Although no sewage is allowed to enter them, yet they receive from the streets an amount of putrescible matter, which requires them to be built on similar principles and with similar care to the regular sewers. The rain water channels examined in Oxford and Reading, the best examples, were not as odorless, when seen in dry weather, as the sewers in Frankfort and Hamburg.

The rain-water from the streets enters the sewers through inlets at the curbs. The designs of these inlets will differ according to circumstances. In Hamburg, where the streets are well paved, the sewers well designed, and where there is an unlimited supply of water in the Alster basin which is used for frequent flushing, it is possible to lead the surface water directly into the sewer without silt basin or trap. In Paris, where it is preferred frequently to wash the street dirt into the sewers instead of carting it away, and where, with the "*bateaux* and *wagons vannes*" a good system of artificial flushing is in use, the silt basins and traps are also omitted, with no objectionable results.

In cities where the same facilities are not had, and where neither streets nor sewers can be cleaned as well, silt basins are necessary to retain all heavy and bulky materials.

The size will depend on their frequency, on the character of pavement and the facilities for cleaning them; their depth must be below the frost line. If not properly attended to they may be very objectionable, yet this feature is common to both systems, when rain-water is led away under ground.

Where sewer exhalations are strong, it will be necessary to insert traps at the inlets to prevent a nuisance along the sidewalks. But this necessity should always be considered capable of being removed by improving existing defects in the system, because the absence of traps, by assisting ventilation, will promote the sanitary condition of the sewer.

It will be seen from these remarks that basins and traps should be avoided, if possible, by making them unnecessary through a good system of cleaning the sewers, and by keeping the rain-water on the surface as long as practicable, the number of inlets themselves could be reduced. The latter necessitates good pavements with slight camber to enable the water to cross intersections, as seen in London, Berlin and Paris. This is particulary advantageous near the summits of the drainage area where the proportionate reductions in the size of the pipes, and therefore saving of expense, will be greatest.

In reviewing what has been said about the combined and separate systems, it is clear that an earnest opposition to either, on sanitary grounds, is not justifiable. If there is any preference it is in favor of the combined system, because it offers on account of the size of the sewers, greater facilities for inspection and cleaning, and decreases the probabilities of stoppages.

A choice will therefore depend mainly on the question of cost, both of construction and maintenance. And in the latter case consideration should be given to the fact, that simplicity of a sewerage system in its design, and as much independence as possible from human aid in its working, can represent considerable value.

Finally, it may be stated that a comparison of our works generally with those in Europe, shows that the chief cause of their unsatisfactory condition lies in the insufficient attention given to maintenance. In this direction, therefore, we need the greatest improvement. Constant care is necessary to preserve even good works in a good state. From the very nature of sewage, in being probably the most heterogeneous substance in existence, this cannot be dispensed with. It will be as obligatory in one system as in the other, but its expense will depend less on their difference than on the manner in which either has been originally built.

General Comparisons and Conclusions.

It now remains to briefly draw a few comparisons between all the systems, and in so doing, it is premised that each one is designed, executed and maintained in a reasonably perfect manner. They are first compared from a sanitary point of view, and then as to their relative expense.

An inspection of the best examples will, we believe, convince one that each can be made to answer the sanitary demands within satisfactory limits, but that the water-carriage system is always preferable to the dry methods on account of its greater cleanliness in the houses and the quick, continuous removal of the filth.

Among the water carriage systems themselves, th re is little difference if they are equally well built and maintained.

The Liernur method is least satisfactory, because the use of water is limited, and many foul substances are left to enter the rain-water channels. But on the street it gives less rise to offensiveness because of the impossibility of gases, if such there are, escaping through any opening.

The ordinary separate system is preferable from a sanitary point of view, whenever rain-water does not need extensive underground removal, when it is necessary to have a system of house drainage with the least possible delay, and when the diluted sewage during storms cannot be permitted to run into the streams.

Its disadvantages have been found to be as follows : The smaller pipes

increase the possibility of stoppage and disorder, and decrease the facilities for cleaning. Duplicate sewers for sewage and rain-water have also been the cause of erroneous connections and, if not absolutely water-tight, have acted and reacted on each other under the street. The channels carrying rain-water alone, including the street wash, will generally become foul if not given nearly the same attention as the combined.

The combined system, on the other hand, is best, from a sanitary point of view, for large areas of thickly populated surfaces, where underground rain-water removal is required. It has the advantage of being only a single system of sewers, which therefore avoids connections to the wrong system, and greatly facilitates maintenance in being more readily inspected and cleaned, both artificially and by the periodical rain storms.

Sanitary imperfections occur only when it is wrongly designed, and badly built or maintained, difficulties to which the duplicate system is also exposed and, from its greater complications, even in a greater measure. Objections made to the combined system, when purification is required, can usually be answered by properly designed intercepting sewers, which receive the foul waters alone, except during a heavy storm, when the sewage is so diluted, that it does not differ materially from the water running off the fields, and can, except in rare cases, be admitted into the stream without fear.

A comparison of the relative cost of the different systems depends so much on local conditions, that it is impossible to state more than very general results. Even with a full knowledge of the locality, it will sometimes require a careful consideration of circumstances to decide which one will be the most desirable and economical.

For a town where, from its position, water supply and density of population, water carriage is at all practicable, it will be less expensive, in spite of its greater first cost, than dry removal, provided the latter would be kept up to a good sanitary standard.

Among the water carriage systems themselves, the relative economy can be decided as follows :

Where storm water must be carried away under ground, as from extensive and closely built up districts, and when new sewers must be built for this purpose, as is generally the case in large or rapidly growing cities, the combined system will be the most economical.

Where storm water can flow away in existing sewers, which are unsuitable for the proper conveyance of sewage, or, when it can be

concentrated in a few channels, slightly below the surface, or can be allowed to run off over the surface, or finally, when purification of sewage becomes very difficult and expensive, it will be more economical to adopt the separate system, *i. e.*, to exclude the rain-water from the sewers receiving house drainage. These conditions will generally be found in towns which have an old system of valley line sewers, or have drainage areas which are very short, very steep, or so flat and low that no sewers can get an outfall without pumping, and finally, in rural districts where the population is scattered.

The separate system will also be the cheapest where necessity arises for a rapid drainage of houses, leaving rain-water out of the question at the time. But if the conditions demand an after provision for storms, by extensive sewers, the final cost will be greater.

When the sewers for rain-water alone must convey as much water as those of the combined system under the above conditions, and works to this effect have to be built anew, there can be no doubt of the greater expense, and although frequently proposed under a presumption of obtaining greater sanitary benefits, such a duplicate system has not yet been carried out, and according to the above conclusion, does not seem warranted.

It is possible, further, to make a combination of both systems in the same town. On some areas it may be found expedient to exclude rain-water and carry it on the surface into a water-course ; on others, which are longer, and include closely built up territory, the combined system may be advisable, and the sewage of both can be united and continued in the same channel.

The cost of the Shone system, which has not yet been extensively tried, would be substantially the same, under the conditions where it is best applicable, as that of the ordinary separate system. The extra cost of compressed air tubes and machinery would be somewhat compensated by a saving of excavation.

Liernur's system is found to be the most expensive to construct, as it requires an iron pipe in every street, and two in those containing the discharging pipes from the numerous reservoirs, besides a system of ordinary sewers for taking away kitchen waste, and, if necessary, the rain-water.

The cost of maintenance for the different systems is even more difficult to estimate generally.

But, leaving dry removal, which is, of course, the most expensive, we can say that it is cheaper to maintain the combined system than the separate, because there is only one set of sewers, and, being large, they are easier to inspect, and less likely to get stopped up. Expense of flushing will usually be the same in both, but the combined has the additional advantage of the scouring of heavy rains.

The cost of maintaining the Shone system will be greater, than by using the ordinary method of pumping, yet other advantages may balance this additional expense in some localities.

The Liernur system again, is also the most expensive to maintain, as the motion of the liquid is produced by artificial power instead of gravity, even where the latter could operate alone on a down grade ; yet this greater cost will be somewhat relieved, as the pipes do not require flushing or cleaning, and a greater return is had from the slightly richer manure.

Finally, the general conclusion which can now be drawn with reference to all of the systems, which is also, it appears, the direction in which an ultimate agreement in the various controversies may be found, lies in the fact that none of the above systems will be applicable for all towns, but different external conditions will demand as radically different solutions, both in general and detail. The dry removal and the separate and combined water carriage will each be satisfactory when confined to certain limits, and where each one will have advantages over the rest.

It may become necessary in some cases to make the most careful inquiry into the existing conditions before a decision can be arrived at, regarding the general system, as well as its details, which will be best suited to the particular locality.

When it is urged at present that a radical change is necessary in our method of sewerage, and that, for instance, the separate system should be adopted under conditions for which we have above designated the combined, it rather seems that this radical change is more necessary and will produce more beneficial results in the direction of improving the details of design, construction and maintenance of the latter, the neglect of which has been the main cause of its shortcomings. And this greater attention and care would, in fact, be no less imperative with the separate and all other systems.

But another change seems to be still more urgent. Although profess-

ing to favor water-carriage, the prevailing method in most American cities is still the use of the most objectionable of devices, the ancient cesspools under or near our dwellings. To abolish them where sewers are within reach, by substituting a carefully planned house drainage, will do more towards raising the sanitary condition of communities than the supposed difference between the two general systems of drainage which presents mainly a question of expediency and cost, because both may be equally good when well designed and managed, and equally bad when neglected.

DISCUSSION.

Charles E. Fowler.—We have in New Haven, Conn., a system of sewerage designed by Mr. E. S. Chesbrough, a member of the Society, which has been working well for ten years. It is what is known as the combined system, and we have not, as yet, experienced to any great extent, the difficulties complained of by the advocates of the separate system. We do not find that filth from the catch basins accumulates in the sewers to an extent sufficient to cause trouble. The principal cause of obstruction in our sewers, and I might say almost the only one, is sand, which reaches the sewers through the catch basins during heavy storms. The water in the catch basins, including any filth that may have accumulated there, is generally carried off in the early part of the storm, and it is only toward the end of the storm, when the basins are filled to overflowing, that the sand gets in. Sand from the basins is removed as soon as practicable, and the basins immediately flushed and filled with clean water from the fire hydrants. Our arrangements for removing the sand from the sewers, and cleaning them, are quite complete, and the work is carried out in a very economical and satisfactory manner. A thorough examination is made, and all sewers cleaned, at least once in each year. In the flushing of the smaller sewers, which cannot be entered by men, we are greatly assisted by the use of wooden balls, two inches less in diameter than that of the sewe

to be flushed. The wooden ball is placed in the sewer and forced from one manhole to another, by water closely confined and discharged in large quantities in rapid succession. The sand forced down is removed from the sewer at the manholes.

New Haven, being somewhat peculiarly situated, could not very well be sewered under the separate system, by a single line of soil pipes. It would be necessary to construct another line for the removal of the storm waters and surface drainage, as there are large areas to be drained that are at a considerable distance from the outlets. In fact, the territory wherein occurs the greatest inconvenience or damage from storm waters is situated at the greatest distance from the harbor, and one of our largest main sewers leads to that district.

Mr. Hering has referred to sewers with "dead ends," and advises that connecting links be made between the ends of the sewers, and sewers in adjoining streets. This plan has been tried at New Haven, with favorable results, the connection being made so as to act as an overflow. The sewers in our system are arranged in a manner to avoid, as far as possible, the construction of "dead ends," as in most cases, the culvert from a catch basin is brought into the end of the sewer. The main sewers, in most cases, being laid out through sections of the city having the least elevation above tide water, there are cases where the lines pass through unsettled portions, and, as might be expected, considerable opposition from land owners is encountered. Of course, the opposition is mainly on account of the expense of the assessment for the sewer, and when it becomes necessary to construct the mains for the relief of thickly settled districts beyond, such objections have to be overruled. In this way we may have to build a half mile, or even a mile of main sewer, where there are very few houses, in order to reach a section of the city needing drainage.

The concentric laying of pipe sewers, especially those of twelve and fifteen inches in diameter is, in my opinion, objectionable, where any great difference exists in the diameter or form. In burning the stoneware pipe, the tendency is to shrink unevenly and to warp. In our sewer contracts, it is provided that the area of the pipes shall not be less than that of a circle of the specified diameter, and the variation in diameter shall not exceed one-half inch. As many of our sewers are laid at minimum grades, and as irregularity in the joints would be liable to cause obstructions, our plan is to prevent, as far as possible, such obstruction

to the flow by laying the "water line" or bottom of the pipe true to the established grade.

Considerable trouble is experienced from foul air in the house drains, but we have had very litttle cause for complaint from its presence in the sewers.

Our greatest trouble just now is from manufacturing concerns turning hot water and steam into the sewers, which is found to seriously injure the cement pipe sewers, and the cement mortar in the brick sewers.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CCXXXI.

(Vol. X.—December, 1881.)

ON UNIFORM STANDARD TIME, FOR RAILWAYS, TELEGRAPHS AND CIVIL PURPOSES GENERALLY.

By SANDFORD FLEMING, M. A. C. E.

PRESENTED AT THE 13TH ANNUAL CONVENTION, JUNE 15, 1881.

The question which I have been requested to bring under the notice of the Convention, although not strictly of an engineering character, from its nature cannot fail to be of interest to the members of the American Society of Civil Engineers, many of whom have taken a prominent part in establishing the great lines of communication on this continent. To the large number of its members connected with the administration and development of the gigantic railway system extending between the two oceans, which in length are but little less than 100,000 miles, the subject becomes one of vital importance.

The occasion strikes me as peculiarly appropriate for submitting for your consideration the subject to which, with your permission, I will briefly refer. The Society meets for the first time beyond the limits of the United States, to find in the Dominion of Canada a cordial welcome. Many of its members, in attending this Convention, must have travelled long distances, and have experienced, in one way or another, some of the difficulties it is proposed should be removed.

The definition of civil time and its scientific determination for railway,

telegraph and all ordinary purposes, is a problem to which a solution is imperatively demanded by the present condition of civilization.

The question has been examined by the American Metrological Society, New York; the Imperial Academy of Science, St. Petersburg; the Royal Society, London, England; the Canadian Institute, Toronto, and other scientific bodies.

Its importance has been fully admitted, and expressions of opinion have been obtained as to the means of overcoming the difficulties which are experienced.

The citizens of the United States, and the subjects of Her Majesty, the Queen, occupy together the greater portion of North America. The most friendly relations exist between us, for, in the main, we are substantially one people, living under different Governments, with laws and customs essentially identical. On all sides we are satisfied to remain separated by our political affinities, having distinct theories and beliefs with respect to systems of government. But science, like every noble virtue, knows no national boundary. In this brief note I can recognize none. In alluding to matters which equally concern the United States and Canada, I shall refer simply to this country or to this continent.

As the continent extends across 105 degrees of longitude, an individual at the western limit finds himself seven hours of recorded time behind another individual at the extreme eastern side at the same moment of absolute time. Much of the intervening country is but thinly settled, but railways and telegraphs traverse from ocean to ocean, and we have every gradation of difference of time between the extreme limit of seven hours.

According to the system of notation which we have inherited from past centuries, every spot of earth between the Atlantic and the Pacific is entitled to have its own local time. Should each locality stand on its dignity, it may insist upon its railway and its other affairs being governed by the time derived from its own meridian. The smaller and less important localities, however, as a rule, have found it convenient to adopt the time of the nearest city. The railways have laid down special standards which vary, as has been held expedient by each separate management. In the whole country there is, so far, an irregular acknowledgment of more than one hundred of these artificial and arbitrary standards of time. The consequences of this system are unsatisfactory. They are felt by every traveller, and in an age and in a country when all, more or less, travel, the aggregate inconvenience and confusion

is very great, and it will be enormously multiplied as time rolls on. If the system already results in difficulties to trouble our daily life, and to lead to embarrassments which often occupy our courts of law, which, indeed, too often are the cause of loss of life, what will be the consequences in a few years, when population will be immensely increased and travel and traffic indefinitely multiplied, if no effort be made to effect a change?

The societies I have mentioned, after careful examination, have united in the opinion that a satisfactory change cannot be made too soon, and they have adopted resolutions pointing to a general uniformity and thorough accuracy in time reckoning. They believe that the course they have recommended will greatly facilitate the daily transactions of business men, greatly increase the safety of the travelling public, and immensely benefit the whole community.

It is proposed that the community unite in an effort to simplify the system now in use by reducing the number of time standards to a minimum by substituting for an indefinite number of irregularly established and purely local standards a few main or, as they may be termed, continental standards, each one having a fixed and well known relation to all the others. It is proposed to have these standards established and maintained by governmental authority; to have them regulated with precision through a common central observatory, and through these standards it is proposed to keep every town, city, railway and steamboat clock throughout the land as nearly as practicable in perfect agreement.

The plan of arrangements favored by the Metrological Society, New York, and the Canadian Institute, Toronto, is to have the standards so established that they will be exactly one hour apart; that is to say, while it would be nine o'clock at one standard it would be eight o'clock at the next to the west, seven o'clock at the following, and so on, by steps of exactly one hour. There would be no difference in the minutes and smaller divisions of time. If the time be ten minutes or thirty minutes past the hour at any one point, it would at the same instant, in absolute time, be ten minutes or thirty minutes past some hour at every point. The hours themselves only would differ, and they would differ only in designation according as the localities were east or west. At the same instant of absolute time every clock in the country would strike either one hour or another; the minute and second hands would always and everywhere be in perfect agreement.

It may be known to gentlemen present that the officers of the United States Signal Service have evinced a deep interest in the question, and in the efforts to establish uniformity, accuracy and simplicity of system throughout the country, General Hazen, Chief Signal Officer, Washington, has expressed his earnest desire to contribute toward the public dissemination of standard time. He considers it eminently proper that the department over which he presides should, as far as practicable, assist in a work in which the whole community is interested, and he offers the active co-operation of the Signal Service in every part of the United States, in the maintenance of accurate standard time and giving it to the public by dropping time balls at all important stations.

Mr. Carpmael, Chief Director of the Meteorological Department of Canada, would similarly co-operate in every practicable way. There would, therefore, be no difficulty in giving effect to a scheme of introducing uniformity of time-reckoning throughout North America, so soon as the railway and telegraph authorities and the general public express concurrence.

It is proposed : 1. That the exact time should be determined astronomically at a central observatory. 2. That every town of any importance should have a public time signal station. 3. That arrangements be made for placing each station in electrical connection with the central observatory at a certain hour every day. 4. That each station be furnished with automatical apparatus for making the proper signal, either by dropping a time ball or by firing a gun at the proper moment. 5. That all the public and railway clocks in each and every locality be controlled electrically from the public time signal station.

I think it may fairly be claimed that no peoples are more progressive or more ready to adopt any needed change or manifest improvement than those who live in North America. And as there is no country except Russia where a greater necessity is presented, or a better field offered for the introduction of a comprehensive system of uniformity in time reckoning, it is more than probable that in this country the change will first be made.

As there can be little doubt that other countries will in due time follow the example of America, it is desirable that we should inaugurate a system which will readily commend itself by its appropriateness and simplicity. One that will have the best prospect of being ultimately adopted throughout the world. If we admit the principle that in a

question of this kind it is not expedient to limit our view to any city or state or province, but to embrace in our system the whole of the continent, it seems to follow that we should take a still broader view, and endeavor to apply the principle to all countries. Steam and electricity are rapidly altering the conditions of life everywhere, they are girdling the globe and bringing all countries nearer together. We get our unit measure of time from the earth's revolutions, it is, therefore, common property, and nothing can be more cosmopolitan in its nature. It is perfectly obvious to my mind that a system of uniform time which would be good for this country should be equally good for all countries on the face of the globe.

These views have met with the ready acquiescence of all who have given them careful consideration, and the system recommended by the several scientific bodies for adoption on this continent, commends itself as a scheme which all nations may, with advantage to themselves and to general interests, accept.

The American Metrological Society and the Canadian Institute have each passed resolutions substantially as follows :

"*Resolved*, That uniformity of time throughout the United States and Canada is demanded by the progress of events, and that a general system by which time may be reckoned in a uniform and accurate manner by the people of all nations throughout the globe is of the highest importance.

"*Resolved*, That a great service will be rendered to the world by directing the public mind to the subject, and by securing the general adoption of a well conceived system of uniformity, and that the Society is hereby authorized to coöperate with other bodies in recommending a comprehensive scheme based on the following propositions :

"1. Twenty-four standard meridians (one every 15 degrees of longitude) to be established around the globe for reckoning sectional or local time.

"2. One of the 24 standards to be selected as a time zero or initial meridian for reckoning cosmopolitan time.

"3. The time zero to coincide with the prime meridian to be common to all nations for computing longitude.

"4. The twenty-four standard meridians to be designated by names,

or by letters of the alphabet, or by degrees of longitude, numbered from the prime meridian westerly.

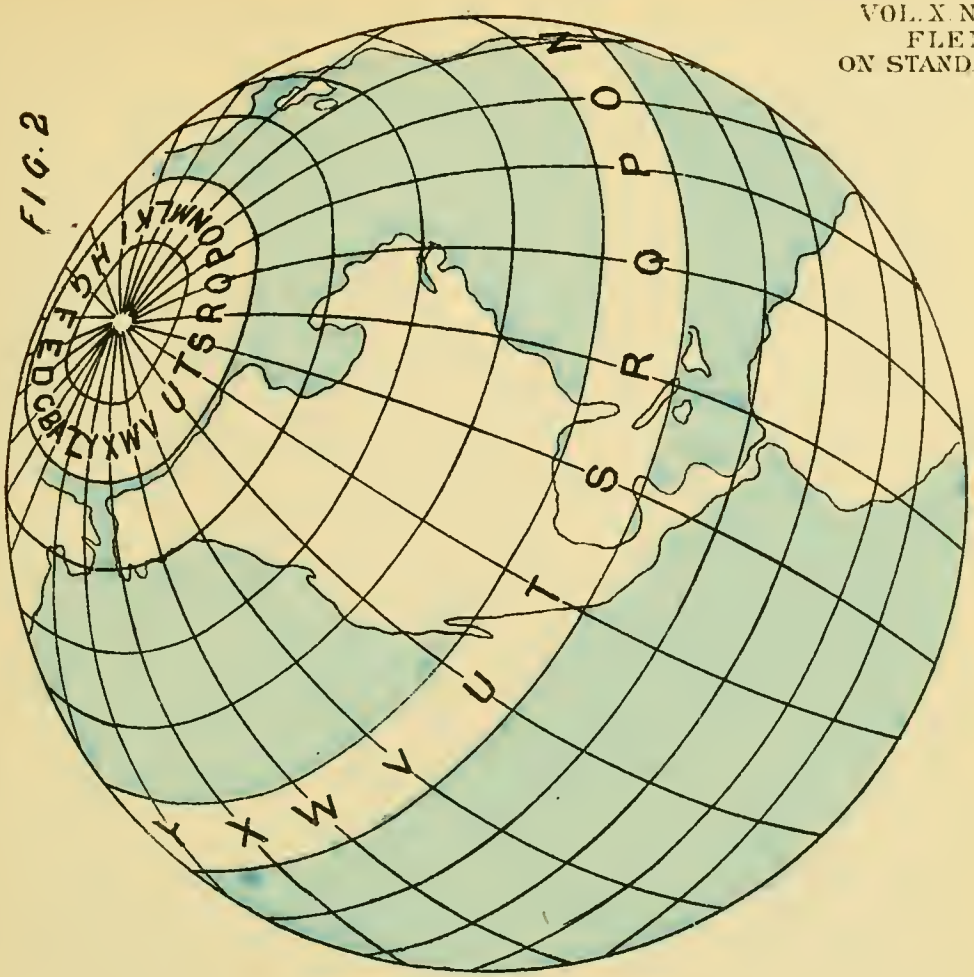
"5. The prime meridian, or zero for time and longitude, to pass near Behring Strait 180 degrees from Greenwich.

"6. The division of the day into two halves of twelve hours each to be discouraged, and a single series numbered from I to XXIV, substituted. In the cosmopolitan day, or period of time between two successive passages of the sun over the prime meridian, the single division to be made absolute."

I may avail myself of this opportunity of mentioning that the scheme of cosmopolitan standard time is being brought before various European societies under distinguished auspices. His Excellency, the Governor-General of Canada, has been good enough personally to evince a deep interest in the question, and has been pleased to send communications to France, Belgium, Prussia, Austria, Russia and Switzerland. The subject will be considered by the Association for the Reform and Codification of the Law of Nations, at their meeting in August next, at Cologne, in Rhine-Prussia; and it will, on that occasion, find warm advocates in Dr. Barnard, President of Columbia College, and Mr. David Dudley Field, of New York. The question will be brought under the consideration of the International Geographical Congress at Venice, in September next, supported by such men as Mr. Otto Strove, Director of the Imperial Observatory, St. Petersburg; General Hazen, of Washington, and others.

In bringing these propositions under the notice of the American Society of Civil Engineers, I do not feel justified, on an occasion like the present, to refer at length to the voluminous papers which have been written, and the arguments which have been advanced, in connection with this question. Necessarily I have been brief, and I respectfully suggest, in order further to save the time of the Convention, that a committee be appointed to examine and report at a future meeting.

I feel it proper to add that as the great object is to determine and establish a system which will secure the greatest advantages to the community, it is of first importance to have the proposition carefully digested by those whose opinions have value with the public. An expression from this body, of educated, scientific and practical men, must carry with it great weight, and will exact respect in every quarter.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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS.

(INSTITUTED 1852.)

VOL. VII.

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— October 12th, 1881, Proposals considered; report on compounding dues received, 114.

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— January 19th, 1881, The Crippling Strength of Wrought Iron Columns; also Inter Oceanic Transit discussed, 3.

— February 2d, 1881, Ballot for Membership canvassed; Ballot canvassed determining Montreal as place for Thirteenth Annual Convention; Ballots for proposed Amendments to the Constitution canvassed, 3.

— February 16th, 1881, Wind Strains upon Bridges discussed, 7.

— March 2d, 1881, Ballots for Membership canvassed; death of A. D. BRIGGS announced; specimens from Egyptian Obelisk presented by H. H. GORRINGE; "Exponent of the Principle of Moments," by W. S. AUCHINCLOSS, read; Wind Strains in Bridges discussed, 7.

— March 15th, 1881, "The removal of the Obelisk from its site in Alexandria, Egypt, to its present site in the Central Park, New York City," by HENRY H. GORRINGE, read, 8.

— April 6th, 1881, Ballots for Mem-

MINUTES.

bership canvassed; arrangements for Annual Convention announced; purchase of premises No. 127 East Twenty third street authorized; advanced subscriptions to purchase made; "An Examination into the Method of Determining Wind Pressures," by F. Collingwood, read and discussed, 13.

— April 20th, 1881, "The Construction of the Second Avenue Line of the Metropolitan Elevated Railroad of New York," by G. Thomas Hall, read, 14.

— May 4th, 1881, Ballots for Membership canvassed; purchase of property No. 127 East Twenty-third street announced; Subscriptions to Building Fund, 19.

— May 18th, 1881, "Quicksand in Excavation," by Charles L. McAlpine, read and discussed; death of Baron von Weber announced, 19.

— June 1st, 1881, Ballots for Membership canvassed; proposed Amendment to Constitution presented; "Quicksand in Excavation" discussed, 61.

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— September 7th, 1881, Ballots for Membership canvassed; death of William Milnor Roberts, of G. Thomas Hall, of James H. Reno, and of William G. Fargo, announced; "Shaft Sinking under Difficulties at Dorchester Bay Tunnel, Boston, Mass.," by D. McN. Stauffer, presented, 87.

— September 21st, 1881, "Shaft Sinking under Difficulties at Dorchester Bay Tunnel, Boston, Mass.," by D. McN. Stauffer, read and discussed, 95.

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— October 19th. 1881, Experiments upon Phœnix Columns discussed, 113.

— November 2d, 1881, Communication received from Engineers' Club Rio de Janeiro, Brazil, expressing sympathy for the death of Past President Roberts; also album of Brazilian Railroad Photographs; committee appointed to make reply; Experiments on Phœnix Columns discussed, 113.

— November 16th, 1881, death of Henry Cartwright announced; Protection against Slips in Clay Slopes, the Lateral Thrust of Earthwork, Supplying Steam Heat and Power to Cities, discussed, 114.

— December 7th, 1881, arrangements made for Annual Meeting; Quicksand in Excavation discussed, 121.

— December 21st, 1881, a note upon the "Recent Railroad Crossing Case at Elmira, N. Y., with reference to the hydraulic questions brought forward," by William R. Hutton, was read and discussed, 121.

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WIMMER, SEBASTIAN.—Admitted as Member, 7, 11.

WOOD, DE VOLSON.—Discussion by, 113.

WORTHEN, WILLIAM E.—Discussion by, 14, 20, 121.—On Committee, 39, 40.—Presides at Meeting, 95.—Proposes Amendment to Constitution, 96.

WORTHINGTON, HENRY R.—Death announced, 1

WROTNOWSKI A. F.—On Committee, 39.—Proposes Amendment to Constitution, 96.

WURTELE, A. S. C.—Discussion by, 114,

YARDLEY, EDMUND.—Discussion by, 121.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—January, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

January 5th, 1881.—The Society met at 8 p. m., William P. Shinn in the chair. Ballots were canvassed, and the following candidates declared elected: As Members—William Robert Eckart, San Francisco, Cal.; John Simpson Walker, Wheeler, Ala.; Francis Milton Wilder, Binghamton, N. Y. As Juniors—Arthur Vaughan Abbott, Brooklyn, N. Y.; John William Ferguson, Rutherford, New Jersey.

A paper, subject "The Strongest of the Bronzes; A Newly Discovered Alloy of Maximum Strength." by R. H. Thurston, Member A. S. C. E., was read by the author, illustrated by models and by samples of bronzes, and discussed by Messrs. Forney, Holley, Shinn, Thurston and Worthen.

The death, on December 17, 1880, of Henry R. Worthington, Member A. S. C. E., was announced, and a committee appointed to prepare a memoir for publication in the Proceedings.

ANNOUNCEMENTS.

At the Meeting of the Society to be held Wednesday, February 16, 1881, at 8 P. M., the discussion will take place of the paper on "Wind Pressure upon Bridges," by C. Shaler Smith, Member A. S. C. E. Advance proofs of this paper have been prepared and furnished to members who might desire to participate in the discussion.

The following resolutions were adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of the differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P.M.

The Library and Conversation Rooms will also, for the present, be open every *Wednesday evening* from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Wednesday evenings both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
Eckart, William R.	P. O. Box 1587, San Francisco, Cal.	January 5, 1881.
Walker, John S.	Huntsville, Ala.	" "

JUNIORS.

Abbott, Arthur V.	21 Water St., Brooklyn, N. Y.	January 5, 1881.
Ferguson, John W.	Ass't. Engineer New York, Lake Erie & Western Railway, Rutherford, N. J.	" "

CHANGES AND CORRECTIONS.

MEMBERS.

Buck, L. L.	124 Bedford Ave., Brooklyn, N. Y.
Gunnell, William C	600 20th St., Washington, D. C.
Johnson, L. M.	Assistant to President Pullman's Palace Car Co., Chicago, Ill.
Masten, C. S.	Chief Engineer St. Louis, Jerseyville & Springfield, R. R., Rochester, N. Y.
Nicholson, George B.	Chief Ass't. Engineer Knoxville & Cincinnatti Southern Railway, Covington, Ky.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—February, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

JANUARY 19TH, 1881.—The Society met at 8 p. m., Vice President Chanute in the Chair.

A discussion by Amory Coffin, Member A. S. C. E., on the paper by C. L. Gates, Junior A. S. C. E., was read by the Secretary.

The subject of Inter-Oceanic Transit was discussed by members present.

FEBRUARY 2D, 1881.—The Society met at 8 p. m., President James B. Francis in the Chair.

Ballots for membership were canvassed, and the following candidates declared elected as Members: Nathaniel Webster Ellis, of Manchester, New Hampshire, and Louis Randolph McLain, of Buchanan, Virginia.

The vote for determining the place for the Thirteenth Annual Convention was canvassed, with the following result:

Montreal received	76	votes.
Niagara Falls received	45	"
The Thousand Islands received	39	"
Other places received	5	"

The City of Montreal was thereupon determined as the place, and it was referred to the Board of Direction to determine the time, and to make arrangements for the Thirteenth Annual Convention of the Society. These will be announced at as early a date as possible.

Ballots for the proposed Amendments to the Constitution were canvassed, with the following results :

Upon the proposed Amendment to Article V (see Proceedings, Vol. VI, pages 84 and 93), there were—

In the Affirmative..... 157 votes.
In the Negative..... 4 "

This Amendment was thereupon declared adopted. The amended Article is as follows :

ARTICLE V.—The officers of the Society shall consist of a President, two Vice-Presidents, a Secretary, Treasurer, Librarian, and five Directors, who shall be elected by written ballot, by a majority of votes, at the Annual Meeting of the Society. The term of office shall begin at the close of the Annual Meeting, and continue for one year, or until other officers are elected. Any vacancy occasioned, by resignation or otherwise, may be filled at the next monthly meeting after notice of said vacancy.

Upon the proposed Amendment to Article XXII (see Proceedings, Vol. VI, pages 84 and 93), there were—

In the Affirmative..... 156 votes.
In the Negative..... 5 "

This Amendment was thereupon declared adopted. The amended Article is as follows :

ARTICLE XXII.—The amount of entrance fee to be paid, as well as the annual dues or assessments for the support of the Society, shall be determined from time to time, at some regular meeting of the Society, provided that notice of intended action thereon shall have been given at a previous regular meeting. No alteration in the amount of said fees or assessments shall apply to the fiscal year during which it is made, but shall take effect on and after the first day in January next succeeding the day of the date of said alteration. Members who become Residents or Non-Residents by removal into or beyond the limits prescribed in Article XXI, shall be subject to assessments in the class in which they were on the day of the Annual Meeting, as may appear upon the records of the Society or by written notice to the Secretary.

Upon the proposed Amendment to Article XXIII (see Proceedings, Vol. VI, pages 84 and 93), there were—

In the Affirmative..... 139 votes.
In the Negative..... 18 "

This Amendment was thereupon declared adopted. The amended Article is as follows :

ARTICLE XXIII.—Honorary Members, not exceeding twenty in number, in all, may be appointed by a unanimous vote of the Board of Direction and such Past Presidents of the Society as shall be at the time Members of the Society and resident in the United States. A person to be eligible as an Honorary Member shall be a gentleman of acknowledged eminence in some branch of engineering. Honorary Members shall be subject to no fees or assessments, and shall not be entitled to vote.

Upon the proposed Amendment to Article XXX (see Proceedings, Vol. VI., pages 84 and 93), there were—

In the Affirmative..... 156 votes.
In the Negative..... 5 "

This Amendment was thereupon declared adopted. The amended Article is as follows :

ARTICLE XXX.—The Annual Meeting for the election of officers and hearing the Annual Reports shall be held on the third Wednesday in January. The Board of Direction shall lay before the meeting a report of the state of the Society, together with a statement by the Treasurer, verified by the Committee on Finance, of the funds of the Society, and the receipts and payments during the year ending on the 31st of December preceding.

Upon the proposed Amendment to Article XXXI (see Proceedings, Vol. VI, pages 84, 90 and 93), there were—

In the Affirmative..... 156 votes.
In the Negative..... 5 "

This Amendment was thereupon declared adopted. The amended Article is as follows :

ARTICLE XXXI.—The annual contributions shall become due for the ensuing year on the first day of January, and shall be payable in advance. It shall be the duty of the Secretary to notify each Member of the amount due for the ensuing year, at the time of giving notice of the Annual Meeting.

Upon the proposed Amendment to Article XIX (see Proceedings, Vol. VI, pages 94 and 97) there were—

For the Amendment as originally proposed and as printed, page 94, Proceedings, Vol. VI, 32 votes.

For the proposed Amendment as amended at the Annual Meeting and as printed, page 97, Proceedings, Vol. VI, 67 votes.

That neither Amendment be adopted, leaving the Article as at present, 59 votes.

These proposed Amendments not having received an affirmative vote of two-thirds of all ballots cast, were declared not adopted.

Ballots were canvassed upon the proposed Amendment to take the place of Section 24 of the By-Laws as printed, page 97, Proceedings, Vol. VI, with the following result—

In the Affirmative..... 32 votes.
In the Negative..... 113 "

This proposed Amendment, not having received two-thirds of all the votes cast, was declared not adopted.

The Board of Direction was requested to consider and report what action the Society should take in reference to the proposed International Exhibition in New York in 1883.

OF THE BOARD OF DIRECTION.

FEBRUARY 2D, 1881.—Applications were considered. Action was taken in reference to the proposed collection of a building fund.

ANNOUNCEMENTS.

A list of the additions to membership in the Society, together with the corrected addresses of all Members whose address is different from that given in the Catalogue of July, 1880. is issued with this number of the Proceedings. This list is corrected to date, and is arranged so that it makes, in connection with the Catalogue of July, 1880, a complete list of the Members of all classes, with their addresses.

All Articles of the Constitution which have been amended since the issue in January, 1879, of the printed copy of the Constitution and By-Laws have been issued to the Members of the Society upon a slip, which can be pasted in the printed copies, thus making those copies, with the addition of the slip, correct records of the present Laws of the Society.

The Thirteenth Annual Convention of the Society will, as determined by the letter ballot canvassed February 2, 1881, be held at Montreal, Canada. The Board of Direction has been requested to determine the time, and to make arrangements for the Convention. These will be announced as soon as possible.

LIST OF MEMBERS.

ADDITION.

MEMBER.

		Date of Election.
Ellis, N. W.	52 Wall Street, New York City, N. Y.	Feb 2, 1881.

CHANGES AND CORRECTIONS.

MEMBERS.

Moore, Charles E. ..... Ass't. Engineer, St. Louis, Jerseyville and Springfield R. R., Jerseyville, Ill.

Rice, E. C. ..... Chief Engineer Louisville, New Albany and St. Louis Railway, 3649 Pine Street, St. Louis, Mo.

Weeks, Harvey R. ..... Div. Engineer Cincinnati Southern Railway, Butlerville, Ind.

JUNIOR.

Crosby, B. L. ..... 40 Cedar Street, Roxbury, Mass.

Resignation.

Warren, G. K. ..... Member ..... Dec. 4, 1880.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—March, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

February 16th, 1881.—The Society met at 8 p. m., Vice-President Chanute in the Chair. The paper upon Wind Strains in Bridges, by C. Shaler Smith, Member A. S. C. E., which was read December 15th, 1880, was discussed by Charles E. Emery and, by letter, by Messrs. Charles Douglas Fox, Robert E. Johnston, G. Bouscaren, Robert Fletcher, A. Gottlieb, W. S. Pope, Charles A. Smith, Don. J. Whittemore and Joseph M. Wilson.

March 2d, 1881.—The Society met at 8 p. m., Vice-President Welch in the Chair. Ballots were canvassed, and the following candidates declared elected: As Members, William Archer, Cincinnati, O.; Henry Adamson Bentley, Newport, R. I.; Theodore Newel Ely. Altoona, Pa.; Benjamin Reece, Toledo, O.; Sebastian Wimmer, New York City, N. Y. As Juniors, William Miller Allaire, New York City, N. Y.; Ward Baldwin, Cincinnati, O.; Francis Newberry Holbrook, Brooklyn, N. Y.

The death of A. D. Briggs, Fellow of the Society, was announced, and a committee appointed to prepare a memoir for publication in the proceedings.

Specimens of stone cut from the Obelisk recently erected in the Central Park, New York, and of the stone of the steps, of the white mortar, of the yellow cement, a piece of one of the steel clamps, of the lead, and of the copper dowels connected with the copper crabs used in Egypt in connection with the Obelisk, were presented to the Society by Lt. Commander Gorringe, U. S. N., and the thanks of the Society tendered to him for these additions to its museum.

A paper by W. S. Auchincloss, Member A. S. C. E. Subject: "Exponent of the Principle of Moments," was read by the author, and an Averaging Machine described in the paper was practically exhibited.

The discussion on the subject of Wind Strains in Bridges, was continued by Messrs. O. Chanute, Joseph P. Davis and Ashbel Welch.

March 15th, 1881.—The Society met at 8 p. m. President James B. Francis in the Chair. A paper by Lt. Commander Gorringe, U. S. N., on "The removal of the Obelisk from its Site in Alexandria, Egypt, to its present Site in the Central Park, New York City," was read by the author and illustrated by special drawings.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chaussées, Paris:

Annales. November and December, 1880.

From American Institute of Mining Engineers, Thomas M. Drown, Secretary, Easton, Pa.:

Transactions. Vol. VIII. May, 1879 to February, 1880.

List of Officers and Members, and Rules of the Institute, November, 1880.

The Wearing Power of Steel Rails in relation to their Chemical Composition and Physical Properties. Charles B. Dudley. Easton. 1881.

The American Bloomary process for making Iron direct from the Ore. Thomas Egleston.

The Chemical Reactions in the Bessemer process; the charge containing but a small percentage of Manganese. Charles F. King.

The cost of Milling Silver Ores in Utah and Nevada. R. P. Rothwell.

On Rail Specifications and Rail Inspection in Europe. C. P. Sandberg.

From Argentine Scientific Society, Don Eduardo E. Clerice, Secretary, Buenos Ayres:

Anales. December, 1880.

From Boston Society of Civil Engineers, S. E. Tinkham, Secretary, Boston:

Proceedings. December, 1880.

Additional Width of Gauge on Railroad Curves. Thomas Doane.

From Henry T. Bovey, Montreal, Canada:

Cribwork in Canada. Henry T. Bovey. London, 1880.

From Burnham. Parry & Williams & Co., Philadelphia:

Illustrated Catalogue, of Baldwin Locomotive Works. Philadelphia, 1881.

From Bureau of Steam Engineering, Washington, D. C.:

Report of the Board to recommend a Standard Gauge for Bolts, Nuts and Screw-threads for the U. S. Navy. May, 1880.

From Hon. Allan Campbell, Comptroller, New York:

Report of the Department of Public Works, Quarter ending September 30, 1880.

From H. Wadsworth Clarke, Syracuse, N. Y.

Proceedings of the Board of Supervisors of the County of Onondaga, N. Y. for 1880.

From Justin Dirks, Amsterdam, Holland:

De Rotterdamsche Waterweg. Justin Dirks, Amsterdam, 1881.

From Engineer Department, U. S. A. Gen. H. G. Wright, Chief of Engineers, Washington, D. C.:

Advertisement for Removing Obstructions from Red River, La.

Specifications for building an Iron Sternwheel Snag Boat. Maj. W. H. H. Benyaurd.

Annual Report of the Engineer in charge of the Completion of the Washington Monument. Col. Thos. Lincoln Casey.

The Harbor at Baltimore. Col. W. P. Craighill.

Specifications for Improvement of Mobile Harbor, Ala. Capt. A. N. Damrell.

The Improvement of Winton Point, Ill. Capt. O. H. Ernst.
Specifications for Improving the Lower Willamette and Columbia Rivers. Maj. G. L. Gillespie.
Specifications for Improving the Upper Columbia and Snake Rivers. Maj. G. L. Gillespie.
Specifications for Improving lower Clearwater River near Lewiston, Idaho, Maj. G. L. Gillespie.
Specifications for Improving Volusia Bar, Florida. Gen. Q. A. Gillmore.
Specifications for Imyrovement of Savannah Harbor and River, Georgia. Gen. Q. A. Gillmore.
Specifications for Improvement of Harbor at Brunswick, Ga. Gen. Q. A. Gillmore.
Specifications for Improving Harbor at Waukegan, Ill. Maj. D. C. Houston.
The damages caused by the Improvement of Fox and Wisconsin Rivers. Maj. D. C. Houston.
Report of Survey of the Calcasieu River, La. Capt. C. W. Howell.
Specifications for continuing Improvement of Pearl River, Miss., from Jackson to Carthage. Capt. C. W. Howell.
Specifications for Improving Bayou Teche, La. Capt. C. W. Howell.
Specifications for Improving Amite River, La. Capt. C. W. Howell.
Specifications for Improving Pearl River, below Jackson, Miss. Capt. C. W. Howell.
Specifications for Improvement of Schuylkill, River, Pa. Col. J. N. Macomb.
Specifications for Improvement of Susquehanna River above Richard Island, Pa. Col. J, N. Macomb.
Reports of Surveys on the Mississippi River at Andalusia, Ill , and Louisiana, Mo. Capt. A. Mackenzie.
Specifications for furnishing Material for the Improvement of Galveston Harbor. Maj. S. M. Mansfield.
Specifications for Improvement Petaluma Creek, Cal. Col Geo. H. Mendell.
Specifications for Improvement of Oakland Harbor, Cal. Col. Geo. H. Mendell.
A Report of the Survey of the Youghiogheny River. Col. Wm. E. Merrill.
Specifications for Ohio River Improvement. Col. Wm. E. Merrill.
Reports of Surveys of the Sumpawaums Inlet, Patchogue River, and waterway connecting Jamaica Bay with Cornell's Landing. Gen. John Newton.
Specifications for Improvement of Raritan River, New Jersey. Gen. John Newton.
Specifications for Improving Buttermilk Channel, New York Harbor. Gen. John Newton.
Report of Survey for a harbor at Kewaunee, Va. Maj. H. M. Robert.
Report on the Maintenance of the Des Moines Rapids Canal Capt. A. Stickney.
Specifications for Rubble Stone in Rockland Harbor, Me. Gen. Geo. Thom.
Specifications for Dredging Exeter Harbor, N. H. Gen. Geo. Thom.
Reports of Surveys of Wareham Harbor and Potowamut River. Gen. G. K. Warren.
Report of Work on Connecticut River. Gen. G. K. Warren.
Specifications for Excavating Material and Constructing Pier Revetment, at the St. Mary's Falls Canal, Mich. Maj. G. Weitzel.
Specifications for Removing Shoals in and around the Harbor of Refuge at Sand Beach, Mich, Maj. G. Weitzel.
Specifications for Fairport Harbor, Ohio. Maj. John M. Wilson.
The Preliminary Report of the Mississippi River Commission.

From Engineers' Society of Western Pennsylvania, Jas. H. Harlow, Secretary, Pittsburgh :

Annual Reports. January, 1881.
Discussion on The Basic Dephosphorizing Process. What is it, and what may be expected from it.
Dam of the Montaubry Reservoir. Lieut. F. A. Mahan.

From Theo's. French, Auditor Railroad Accounts, Washington:

Annual Reports for 1878, 1879, and 1880.

From Fred. de Funiak, Gen. Man. Louisville and Nashville R. R. Louisville:

Annual Report year ending June 30, 1880.

From Charles O. Gleim, Cologne, Germany:

Das techniche Vereinswesen des Auslandes und die daraus zu ziehende Nutzanwendung für die. Deutschen Verhältnisse. Gustav Meyerand C. O. Gleim. Berlin. 1880.

From Robert B. Gorsuch. Mexico:

The Mexican Southern Railway, to be constructed under a Charter from the Mexican Government, through the States of Vera Cruz and Oaxaca. Robert B. Gorsuch. New York, 1881. (*Copies for distribution.*)
The Republic of Mexico and Railroads. A brief review of her past history and present condition. Robert B. Gorsuch. New York, 1881. (*Copies for distribution.*)

From E. J. Habich, Lima, Peru:

Anales de Constructiones Civiles y de Minas del Peru. Tomo 1. Lima, 1880.
Etudes Cinématiques. M. E. J. Habich. Paris, 1879.

From Institution of Civil Engineers, James Forrest. Secretary. London:

Annual Report of the Council for 1880.
Report at the Annual General Meeting held December 21, 1880.
Address of James Abernethy, President. January 11, 1881.
Dredging and other Plant employed at the Quebec Harbor Works. St. George J. Boswell.
The Monte Penna Wire Ropeway. William P. Churchward.
Sandy Island Lighthouse, Antigua, West Indies. L. A. E. Mackinnon.
The Co-Efficient of Friction of Air Flowing in Long Pipes. William C. Unwin.
The River Weaver Navigation. John W. Sanderman.
Machinery for Steel-Making by the Bessemer and the Siemens Processes. Benjamin Walker.

From Institution Mechanical Engineers, Walter R. Browne, Secretary, London:

Proceedings. August, 1880. Barrow Meeting

From the Iron and Steel Institute, London:

Journal of the Institute. No. 2. 1880.

From Hon. Edward Learned, New York:
The Tehuantepec Inter-Ocean Railroad. Alex. D. Anderson.

From Lyceum of Natural History, Albert R. Leeds, Cor. Secretary, New York:
Index and Contents. Annals of the Lyceum Vol. XI. No. 13. New York, 1876.

From Massachusetts Institute of Technology, Boston:
Abstract of Proceedings of the Society of Arts for 1879-80.
Sixteenth Annual Catalogue of the Officers and Students of the Institute 1880-81.

From Miles Meriwether, Memphis, Tenn.:
Biennial Report of President of Fire and Police Commissioners of Taxing District, Memphis, Tenn. December 1, 1880. (2 Copies.)

From Midland Institute Mining, Civil and Mechanical Engineers, Barnsley, England:
Transactions, September, October and November, 1880.

From George S. Morison, New York:
Forty-sixth Annual Report of Eastern Railroad Co. Boston, 1880.
Detailed plans, &c. Plattsmouth Bridge, Nebraska. Geo. S. Morison, Chief Engineer.

From New York Academy of Sciences, New York:
Annals. September, 1879, March and April, 1880.

From Edward P. North, New York:
Hackney Carriages. Tables of Distances within a circle of four miles radius from Charing Cross, London. 1878.

From North of England Institute, Mining and Mechanical Engineers, Theo. Wood Bunning, Secretary, Newcastle-on-Tyne, England:
Transactions. September, October and November, 1880.

From W. C. Oastler, New York:
Hints about Roadways and Steam Road-Rolling. W. C. Oastler, New York. 1881. 3d Edition.

From P. A. Peterson, Montreal, Canada:
Report to Quebec, Montreal, Ottawa and Occidental Railway Commissioners on the propriety of changing the Terrebonne location of the North Shore Railway, between the Western Edge of the "Grand Savane" and Montreal, back to the original or Bout de l'Isle route. P. A. Peterson. Quebec. 1880.

From Edward S. Philbrick, Boston:
American Sanitary Engineering. E. S. Philbrick. New York, 1881.

From Pi Eta Scientific Society, Troy, N. Y.:
Papers read before the Society as follows: Vol. II., No. 1.
Notes on Railroading. A. L. Waddell.
Theory of the Masonry Arch. Wm. H. Burr.
Braced Iron Piers. Thomas M. Cleemann.

From Edward Prince, Quincy, Ill.:
Sny Island Levee. A History of Legislation relating to it, and a Criticism of the System of Engineering adopted. Were the Levees properly and scientifically constructed? E. Prince. 1880.

From F. C. Prindle, U. S. Navy Yard N. Y.:
Annual Reports of Engineer in charge of Construction Washington Monument, years ending November 30, 1879 and 1880. Col. Thos. Lincoln Casey,
Report of Commission showing extent and progress made in the work for the completion of Washington Monument, and the amount of money expended.

From Publishers Révue Génerale des Chemins de fer. Paris.
Revué Generale des Chemins de fer. October and November, 1880.

From I. W. Raymond, San Francisco:
San Francisco System of Wire Rope Street Railroads.

From Col. W. Milnor Roberts, Rio de Janeiro, Brazil:
Report of Hydraulic Commission to examine Sao Francisco River 1879-80. W. Milnor Roberts, Chief Engineer, Rio de Janeiro. 1880.

From Hon. Horatio Seymour, Jr., State Engineer and Surveyor, Albany, N, Y.:
Report on Prosperity of New York Canals. Horatio Seymour. Albany, 1881. (Several copies.)

From T. Guilford Smith, Buffalo, N.Y.:
Statement of the present condition of Philadelphia and Reading Railroad and Phila. and Read. Coal and Iron Co. with plans for their further financial reorganization. Franklin B Gowen, 1880.

From Société des Ingenierus Civils Paris:
Memoires. October, November and December, 1880,

From St. Louis Public School Library, St. Louis:
Bulletin. No. 11. September-October, 1880.

From Americus Symmes, Louisville, Ky.:
The Symmes Theory of Concentric Spheres. John C. Symmes. Louisville, 1878.

From United States Association of Charcoal Iron Workers, John Birkinbine Secretary, Harrisburg, Pa.:
Journal of the Association. Vol. II, No. 1. January, 1881.

From United States Light House Board, Washington, D. C.:
Annual Report of the Light House Board for year ending, June 30, 1880.
List of Beacons, Buoys, Towers and other Day Marks in the Eighth Light House District, corrected to December 31, 1880.

From United States Naval Institute, Annapolis, Md.:
Proceedings. Vol. VI. No. 13.

From D. H. Van Auken, Cohoes, N. Y.: Photograph and Description of Centering Arch over New Canal through Ontario St., Cohoes, N. Y. D. H. Van Auken, C. E. 1880.

From A. F. Wrotnowski, New Orleans: Report of the Louisiana Land Reclamation Company. Columbus H. Allen. New Orleans, 1880,

From other sources:

Proceedings of the meeting to draw up Articles of Association between sundry Engineering Societies and Clubs for the purpose of securing a joint Publication of Proceedings, held at Chicago, December 4, 1880.

Reference Catalogue of Current Literature. New York, 1880.

Annual Report of Columbia Oil Co. Pittsburgh, 1880.

The Library Journal. Vol. V. Nos. 11-12. Vol. VI No. 1.

ANNOUNCEMENTS.

The Thirteenth Annual Convention of the Society will be held at Montreal, Canada, on June 15th, 1881. The Board of Direction has been requested to make arrangements for the Convention. These are in progress and will be announced as soon as possible.

The following resolutions were adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications :

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of the differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

The House of the Society is at 104 East Twentieth street, one door east from Fourth avenue, and near the southwest corner of Gramercy Park. It is open from nine o'clock A.M. to five o'clock P.M. each business day, except Saturday, when it is closed at three o'clock P.M.

The Library and Conversation Rooms will also, for the present, be open every *Wednesday evening* from 7½ to 10 P. M. Members are invited to avail themselves of the opportunities afforded on Wednesday evenings both for consultation of books and periodicals and for conversation.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
ARCHER, WILLIAM	Engineer Marietta & Cincinnati R. R. Cincinnati, Ohio	March 2, 1881
BENTLEY, HENRY A.	Newport, R. I.	" "
ELY, THEODORE N.	Superintendent Motive Power Department P. R. R., Altoona, Pa.	" "
REECE, BENJAMIN	Engineer M. S. Division L. S. & M. S. Railway, Toledo, Ohio	" "
WIMMER, SEBASTIAN	Chief Engineer New York City & Northern R R., Room 56, Drexel Building, New York	" "

JUNIORS.

		Date of Election.
BALDWIN, WARD	Assistant Engineer Cincinnati Southern Railway, Cincinnati, Ohio	March 2, 1881
HOLBROOK, FRANCIS N.	Care J. P. Holbrook, P. O. Box 1624, New York	" "

CHANGES AND CORRECTIONS.

BILLIN, CHARLES E. ..... Indianapolis, Ind.

CHITTENDEN, S. H. ..... Sup't Lake Valley Mining Co., Lake Valley, N. M.

GREENE, BENJAMIN H. ... Chief Engineer New Orleans Pacific R.R., Shreveport, La.

HARLOW, JAMES H. ..... Engineer Monongahela Navigation Co., 81 Wood Street, Pittsburgh, Pa.

JOHN, IRVIN ..... Fleming Building, Room 6, Jersey City, N. J.

MCCLINTOCK, W. H. ... Assistant Engineer Louisville & Nashville R. R., Bowling Green, Ky.

NICOLLS, WILLIAM J. ... General Manager Snowshoe Coal Co., Bellefonte, Pa.

POST, JAMES C ..... Captain of Engineers, U. S. A., Newburgh, N. Y.

STEPHENS, CLINTON F. ... Chief Engineer Texas & St. Louis Railway, Corsicana, Texas.

WISNER, GEO. Y. ..... 2828 Washington avenue, St. Louis, Mo.

WURTELE, A. S. C. ..... New York Central & Hudson River Railroad, 19 Jay street, Albany, N. Y.

JUNIOR.

WHITNEY, SAMUEL ..... New Orleans & North Eastern R. R., Meridian, Miss.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—April, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

April 6th, 1881.—The Society met at 8 p. m. Vice-President Chanute in the Chair.

Ballots were canvassed and the following candidates declared elected: As Member, Charles Rufus Boyd of Wytheville, Va.;—As Associate, Henry H. Gorringe, of New York;—As Junior, Edward Butts, of Kansas City, Mo.

The Secretary reported that the date of the next Annual Convention was fixed as June 15th, and that arrangements were in progress as to the proceedings at that date at Montreal.

The Board of Direction reported the results of their action in reference to securing more permanent quarters, and brought to the notice of the Society the house No. 127 East Twenty-third street, New York.

The following resolution was adopted: That the Board of Direction be authorized to purchase the property No. 127 East Twenty-third street, at a price not exceeding thirty thousand dollars.

In order to secure this property a payment of $5,000 was required. The subscription to the Building Fund did not yet amount to $10,000, and under the terms could not be immediately called in. The following named ten members of the Society advanced the sum of five hundred dollars each, to be repaid from subscriptions; James B. Francis, O. Chanute, Ashbel Welch, E. S. Chesbrough, William E. Worthen, Walter Katté, Charles Macdonald, L. B. Ward, A. L. Holley, Eckley B. Coxe.

A paper by F. Collingwood, Member A. S. C. E., on "An Examination into the Methods of Determining Wind Pressures," was read by the author and discussed by Messrs. Chanute, Chesbrough and Worthen.

April 20th, 1881.—The Society met at 8 p. m. Past President Greene in the Chair.

A paper by G. Thomas Hall, Member A. S. C. E. Subject; "The Construction of the Second Avenue Line of the Metropolitan Elevated Railroad of New York," was read by the Secretary and discussed by Members present.

OF THE BOARD OF DIRECTION.

February 25th, 1881.—Applications were considered. The Secretary was directed to make preliminary arrangements for the next Annual Convention. A form for an additional circular in reference to the collection of a Building Fund was determined upon and its issue ordered. Appropriations were made.

March 23d, 1881.—Applications were considered. Arrangements for the approaching Annual Convention were discussed. Appropriations were made.

April 5th, 1881.—Applications were considered. Arrangements for the Convention were made. The following resolutions were adopted:

Resolved, That Messrs. W. H. Paine, C. Vandervoort Smith and Joseph P. Davis, be instructed to act as Trustees for the Building Fund, with instructions to collect the same from the subscribers and to deposit the proceeds in some trust company or savings bank offering due security, so that the signatures of at least two of the Trustees or their successors shall be required to draw out the funds.

Resolved, That the Building Fund shall only be invested upon an order signed by a majority of the whole Board of Direction.

The Secretary reported as to a number of houses examined by him, giving location, size and price. A committee was appointed to further examine houses suitable for purchase and to present the subject at the next meeting of the Society.

April 23d, 1881.—Applications were considered. Resolutions were adopted as advised by the Counsel of the Board in reference to the purchase of the property No. 127 East Twenty-third street, New York, and as to the execution of a bond and mortgage on the same by the designated officers of the Society.

Arrangements were made as to the occupation of the new Society House.

ANNOUNCEMENTS.

The Thirteenth Annual Convention of the Society will be held at Montreal, Canada, June 15th, 1881. Arrangements are in progress to have such of the Members as desire to do so, meet at Niagara Falls on Saturday, June 11th, and examine the new suspended structure of the railroad suspension bridge, and the re-enforcement of its anchorage. A paper on this subject will be presented at the Convention by L. L. Buck, Member A. S. C. E., the Engineer in charge of the work.

After spending Sunday at Niagara, the party will proceed to Toronto, and after a short stay at that city, will go to Montreal by a steamer, on Lake Ontario, passing on Tuesday the Thousand Islands and the Rapids of the St. Lawrence, and arriving at Montreal the evening before the day of the opening of the Convention.

The arrangements at Montreal are in charge of a Committee, and will be duly announced.

Members who cannot make the trip by way of Niagara and Toronto can go directly to Montreal, and should arrive there by June 15th.

Possession of the newly purchased House of the Society has been obtained during the last week of April. Its location is No. 127 East 23d street. It is near Madison Square, the great hotels, and the stations of the Elevated Railroads, and has a number of lines of surface street railroads in the immediate vicinity.

The House of the Society will, as heretofore, be open from nine o'clock a. m. to five o'clock p. m. each business day except Saturday, when it is closed at three o'clock p. m.

The Library and Conversation Rooms will also, for the present, be open every *Wednesday evening* from 7½ to 10 p. m. Members are invited to avail themselves of the opportunities afforded on Wednesday evenings for consultation of books and periodicals, and also for conversation.

The following resolutions were adopted at the Ninth Annual Convention of the Society, and ordered printed regularly in the Society publications:

Whereas, the metric system of weights and measures is now extensively used abroad, and whereas it is desirable that the relation of the units of the differing systems be made familiar to all by comparison:

Resolved, That members be requested, in papers hereafter presented to the Society, to write, in parenthesis, weights or dimensions by the metric system, in connection with those of the system in general use.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Administration des Ponts et Chaussées, Paris:

Annales. January, 1881.

From American Society Mechanical Engineers, Thomas Whiteside Rae, Secretary, New York:

Proceedings. 1st Annual Meeting American Society Mechanical Engineers. New York, November 4 and 5, 1880.

President's Inaugural Address at First Annual Meeting American Society Mechanical Engineers. R. H. Thurston, New York.

An Adaption of Bessemer Plant to the Basic Process. A. L. Holley, New York.

The Field of Mechanical Engineering. A. L. Holley, New York.

High Ratios of Expansion and Distribution of Unequal Pressure in Single and Compound Engines. J. C. Hoadley.

The Metric System; is it wise to introduce into our Machine Shops. Coleman Sellers.
Friction as a Factor in Motive Power Expenses. Prof. John E. Sweet.

From Argentine Scientific Society, Don Eduardo E. Clerice, Secretary, Buenos Ayres:
Annales. January, 1881.
La Vida y Costumbres de los Termitos.

From Appleby Brothers, London:
Appley's Handbook of Machinery.
Section 1. Prime Movers.
" 2. Hoisting Machinery.
" 3. Pumping Machinery.

From Capt. Douglas Galton, London:
The Effect of Brakes on Railway Trains. 1st Paper. Douglas Galton.
Effect of Brakes on Railway Trains. 2d Paper. Donglas Galton.
Effect of Brakes upon Railway Trains. Douglas Galton.
Recent Brake Experiments upon the Lyons Railway. M. George Marie. London.
Memorandum on Brake Experiments made on the North Eastern Railway Co., at York, on July 14 and 15, 1879, upon a train fitted with the Westinghouse Automatic Brake. Douglas Galton.
Reports on Brake Experiments made at Gisburn on the Lancashire and Yorkshire Railway, July 14 and 15, 1880. Douglas Galton.

From J. M. Goodwin, Cleveland:
The Panama Ship Canal and Inter-oceanic Railway Projects. J. M. Goodwin. Cleveland, 1880.

From R. Gordon, Henzada, British Burmah:
Report on the Irrawaddy River.
Part 1. Hydrography of the Irrawaddy.
Part 2. Hydrology of the Irrawaddy.
Part 3. Hydraulics of the Irrawaddy.
Part 4. The Hydraulic Works connected with Nawoon River. R.Gordon. Rangoon, 1880.

From Charles A. Ashburner, Philadelphia:
The Geology of McKean County and its connection with that of Cameron, Elk and Forrest. Charles A. Ashburner, Harrisburgh, 1880.
Maps and Charts of McKean Co., Penna. Charles A. Ashburner. Harrisburgh, 1880.

From William S. Barbour, Cambridge, Mass.:
Mayor's Address and Annual Reports of City of Cambridge, Mass. Cambridge, 1881.
Annual Report City Engineer Cambridge, November 3, 1880. Cambridge, 1881.
Sixteenth Annual Report Cambridge Water Board. Cambridge, 1881.

From Board of Supervisors, John A. Russel, Clerk, San Francisco, Cal.:
Municipal Reports of San Francisco for year ending June 30, 1880.

From Boston Society of Civil Engineers. S. E. Tinkham, Secretary, Boston:
Proceedings January and February, 1881.
Railroad Signals. Geo. W. Blodgett.
Report on Metric System.
Fall River Bridge. E. N. Winslow.

From H. W. Clarke, Syracuse, N. Y.:
Report of Commissioners of New York and Pennsylvania Boundary Line to the Regents of the University of the State of New York. Albany, 1881.
Report of the Regents of the University of the State of New York on Resurvey of the Boundary line, New York and Pennsylvania. Albany, 1880.

From A. Durand-Claye, Paris, France:
Conferences sur l'Assainissement Municipal. Ecole des Ponts et Chaussées, 1871, 1875. A. Durand-Claye, Paris.
Sur les temprietur des eaux sunterraines de Paris pendant les Mois de Decembre, 1879. A. Durand-Claye. Paris, 1879.
Enquête sur les Stations Agronomiques. A. Durand-Claye. Paris, 1878.
Communication sur l'assainissement des Villes. A. Durand-Claye. Paris, 1880.
Mémoire sur le Déssechement du lac Funcino. A. Durand-Claye. Paris, 1878.
Etat de la Question des Eaux d'Egout en France et al 'Etranger. A. Durand-Claye. Nancy. 1877.
Situation de la Question des Eaux d'Egout et de leur emploi Agricole en France et a l'Etranger. A. Durand-Claye. Paris, 1873.

From M. Coryell, Lambertville, N. J.:
Fourth Annual Report of Lambertville Water Co. Lambertville, 1877.

From James B. Eads, St. Louis:
The Isthmus Ship Railway, *North American Review*. March, 1881. James B. Eads. 1881.

From John W. Hill, Cincinnati:
Report of the Expert on the Test Trials of Automatic Cut-off Steam Engines at the First Millers International Exhibition, Cincinnati, June, 1880.

From W. R. Hutton, Baltimore:
Three Photographs showing Lock and Dam of Kanawha River Improvement.

From Institution of Civil Engineers, James Forrest, Secretary, London:
Abstract of Papers in Foreign Transactions and Periodicals. Session 1880-81. Part I.
New Zealand and Ceylon Government Railways. James P. Maxwell and James R. Mosse.
The Different modes of erecting Iron Bridges. Theophilus Seyrig.
Ultimate Working Strength of Materials. Dr. J. Weyrauck.

From Institution Mechanical Engineer, Walter R. Browne, Secretary, London:
Proceedings. October, 1880.
Index, Contents and List of Members, Institution of Mechanical Engineers for 1880.
On Implements and Machinery for Cultivating Land by Horse Power. W. R. Bunsfould.
On recent improvements in the Machinery for Reparing and Spinning Cotton. Eli Spencer.

From W. S. Johnston, Chester, Pa.:
Memoir of Edwin Ferry Johnson, Civil Engineer. Philadelphia, 1880.

From Louis H. Knapp, Buffalo, N. Y.:
Specifications for the Intercepting Sewer, City of Buffalo.

From Charles Neilson, New York:
Drawings accompanying the report of Capt. Turnbull on Surveys and Construction of Alexandria Aqueduct, July 2, 1838. Washington, 1838.

From Publishers Rèvue Génerale des Chemins de fer. Edgar Monjean, Secretary, Paris:
Rèvue Generale des Chemins de fer. December, 1880.

From Royal United Service Institution, Capt. B. Burgess, Secretary, London:
Journal of the Institution. Vol. XXIV. No. CVIII.

From William F. Shunk, New York:
Gilbert Elevated Railway; a collection of facts in reply to the pamphlet "The opinions of Two Eminent Civil Engineers" on Rapid Transit. Wm. F. Shunk, New York, 1877.

From Société des Ingenieurs Civil. Paris:
Memoires, December, 1880, and January, 1881.

From St. Louis Public School Library:
Bulletin No. 12. November and December, 1880.

From United States Coast Survey, Washington:
Annual Report United States Coast and Geodetic Survey, 1877. Washington, 1880.

From U. S. Naval Observatory, Rear Admiral John A. Rogers, Supt., Washington:
Reports on the Total Solar Eclipses of July 29, 1878, and January 11, 1880. Washington, 1880.

From William Watson, Boston:
A report to the American Social Science Association on Protection of Life from Casualties in the use of Machinery. William Watson. Boston, 1879.

From Welton and Bonnett, Waterbury, Ct.:
Fourteenth Report of the Board of Water Commissioners of the City of Waterbury. Waterbury, 1881.

From H. M. Wightman, Boston:
Annual Report of the City Engineer of Boston for the year 1880 (2 Copies.)

From other sources:
The Library Journal. Vol. VI. No, 12.
The Architectural Employment of Terracotta. A Reprint from *The Builder*, August 14 and 11, 1880. New York, 1881.
Length of Tracks of Railroads owned, leased, operated, and controlled by the Pennsylvania Roilroad Co. December 31, 1880.
Twelfth Annual Report of the Board of Railroad Commissioners of Massachusetts. Boston, 1881.
Narrative of the Second Artic Expedition made by Charles F. Hall. Prof. J. E. Nourse. Washington, 1879.
Narrative of the North Polar Expedition U. S. Ship Polaris, Capt. Charles F. Hall, Commanding. C. H. Davis, U. S. N. Washington, 1876.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

ALDRICH, TRUMAN H....Montevallo Coal Mines, Montevallo, Ala...May 4, 1881
BLAND, GEORGE P.....(Elected Junior, April 7th, 1875,) 3214 Woodland Ave., W. Philadelphia, Pa. " "
BOYD, CHARLES R.....Wytheville, Va.....April 6, 1881
LEWIS, SIDNEY F..... Ass't. State Engineer, 289 Royal St., New Orleans, La.....May 4, 1881

ASSOCIATE.

HADDOCK, ARBA R.....410 E. 14th St., New York City, N. Y....May 4, 1881

JUNIORS.

BUTTS, EDWARD.....Ass't. Engineer Kansas Pacific Railway, Erie, Col.....April 6, 1881
FERRY, CHARLES A.....Ass't. City Engineer, 18 City Hall, New Haven, Conn.....May 4, 1881
POETSCH, CHARLES J.... Ass't. City Engineer, Milwaukee, Wis..... " "

CHANGES AND CORRECTIONS.

MEMBERS.

CHILDS, JAMES E.....Gen. Supt. New York, Ontario and Western R. R., Middletown, N. Y.
CLARKE, THOMAS C.....49 William St., Room 58, New York City, N. Y.
COGSWELL, WILLIAM B...109 Willow St., Syracuse, N. Y.
CORTHELL, E. L.....North Egremont, Mass.
FALCONNET, EUGENE F..Pres. and Engineer N. & T. R. R., Nashville, Tenn.
FORCE, CYRUS G., JR....Cleveland, Ohio.
GLOVER, O. L.....Engineer Iquique R. R., Iquique, Peru, S. A.
HARDING, GEORGE E.....40 Exchange Place, New York City, N. Y.
HARDING, HENRY.....P. O. Box 280, Salem, Mass.
HUGHES, WILLIAM M....Engineer Bridges N. Y. C. & St. L. Rwy., 32 Board of Trade, Cleveland, Ohio.
KINSLEY, THOMAS P.....Horseheads, Chemung, Co., N. Y.
LEVERICH, GABRIEL.....Engineers' Office East River Bridge, 279 Front St., New York City, N. Y.
McLAIN, LOUIS R.....Res. Eng. Rope Ferry Bridge, Lorraine, Va.
MEIER, EDWARD D.....214 Pine St., St. Louis, Mo.
SCHMIDT, MAX E.....Care James Harrington, Tampico, Mexico.
SEDGWICK, THOMAS S....1009 O St., N. W. Washington, D. C.
SICKELS, T. E.....90 Broadway, New York City, N. Y.
SITES, WILMON W. C.....Chief Engineer Board Public Works, Jersey City, N. J.
TOWLE, STEVENSON.....Engineer in charge of Sewers, 25 Chambers St., New York City, N. Y.
WILSON, HENRY W.....435 Chestnut St., Philadelphia, Pa.
WILSON, JOHN A... .....435 Chestnut St., Philadelphia, Pa.
WILSON, JOSEPH M.....435 Chestnut St., Philadelphia, Pa.
WIMMER, SEBASTIAN.....71 Broadway, New York City, N. Y.

ASSOCIATES.

HARRIS, CHARLES M.....67 William St., New York City, N. Y.
LAWSON, L. M.... .....102 Broadway, New York City, N. Y.

JUNIORS.

CROSBY, B. L.....Ass't. Engr. Bismarck Bridge, Bismarck, Dak.
LUCAS, D. JONES.....Lock Box 33, Lebanon, Pa.
STAATS, ROBERT P.....39 W. 12th St., New York City, N. Y.

FELLOWS.

COURTWRIGHT, MILTON. .55 Broadway, New York City, N. Y.
GURNEE, W. S.... .....35 Nassau St., New York City, N. Y.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—May, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

May 4th, 1881.—The Society met for the first time in its newly purchased house, at 8 p. m. Past President Greene, in the chair.

Ballots were canvassed, and the following candidates declared elected: As Members—Truman H. Aldrich, of Montevallo, Ala.; William H. Atwood, of Jersey City, N. J.; George P. Bland (elected Junior April 7, 1875), Philadelphia; E. E. Glaskin (elected Junior April 5, 1876), London, Eng.; George T. Keith, of Olean, N. Y.; Sidney F. Lewis, of New Orleans, La.; Henry S. Munroe, of New York; Albert C. Savage, of Belle Plain, Texas; William N. Symington, of New York; Arthur M. Wellington, of Laredo, Mexico; Samuel Whinery (elected Junior April 1, 1874), Meridian, Miss. As Associate—Arba Read Haddock, of New York. As Juniors—Charles A. Ferry, of New Haven, Ct.; Charles J. Poetsch, of Milwaukee, Wis.

The Secretary reported that the property No. 127 East Twenty-third street, New York, had been purchased at the price of $30,000; that $5,000 cash had been paid, and a mortgage executed for the balance, $25,000, for five years, at 5 per cent. per annum, with a provision for the payment of any portion of this amount at any time in sums not less than $1,000. Also that the subscriptions now amount to $10,100, and that a circular had been prepared calling for their payment.

May 18th, 1881.—The Society met at 8 p. m. Director Joseph P. Davis, in the chair.

The Secretary announced the death, on April 18th, 1881, of Max Maria, Baron Von Weber, Honorary Member of this Society, and the President was authorized to appoint a committee to prepare a memoir for publication.

A paper by Charles L. McAlpine, Member A. S. C. E., subject, "Quicksand in Excavation," was read by the author, and discussed by Messrs. Bogart, Joseph P. Davis, Raymond, Torrey, and Worthen.

OF THE BOARD OF DIRECTION.

May 7, 1881.—Applications were considered. The Treasurer reported the collection of over $5,000 of the Building Fund subscriptions, and was authorized to repay that amount to the members of the Society who had advanced the same for the first payment on the purchase of the property. The thanks of the Board were ordered transmitted to these gentlemen.

The Trustees of the Building Fund reported arrangements made for the deposit of its proceeds in a trust company.

The Secretary reported the preparation of the following circular, the issue of which was approved :

May 5, 1881.

Sir :

I am instructed to acquaint you with the fact that the property

No. 127 East Twenty-Third Street, New York,

has been purchased by the American Society of Civil Engineers, and that during the past week the Society has taken possession, and will hereafter occupy the house at that location.

You have been informed, by previous circulars, of the establishment of a Building Fund, and of the provision that subscriptions to that fund would be binding when $10,000 should be subscribed. During the month of March, many houses were visited and examined by the Board of Direction and the Committee entrusted with that duty ; and at the meeting of the Society of April 6th, a report was made of the result of these examinations. It was then decided to purchase this house. To secure the property a payment of $5,000 was necessary. The subscriptions to the Building Fund, at that time, did not amount to $10,000, and, therefore, could not be called in. A prompt decision on the subject was necessary, because the lease of the house then occupied in Twentieth Street expired on May 1st, and had either to be renewed or given up at once. Ten members of the Society directly advanced $500 each. The title of the property was thoroughly examined and the purchase completed, by the payment of $5,000 on April 26th. The price of the property is $30,000, and on the remaining sum of $25,000 interest is

now running at 5 *per cent.* Since the purchase, subscriptions have been received, so that the total subscription is now $10,600. These will be directly called in, and the advance made by members repaid to them. The amount remaining due on the property will be reduced as subscriptions are paid, a provision allowing this being incorporated in the mortgage.

The house is twenty-five feet wide, about sixty feet deep, with a lot in the rear forty feet deep. The house is excellently built, with Ohio stone front and brick sides and rear. It is four stories high, with basement and cellar. It affords at once much more convenient accommodations than the Society has heretofore possessed for its library, its meetings, and for the general uses of members and visitors. The location and construction of the house are such as, in the opinion of careful judges of real estate, will assure its security as an investment and a probable advance in value.

This decided action of purchasing a house has been largely determined upon, in accordance with the advice and suggestions of many members of the Society to the effect that, in order to secure a Building Fund, some decided action was imperative.

The subscriptions have varied in amounts from small sums up to one of $2,500, which latter has been made by one member. Quite a number of subscriptions have been made by persons not members of the Society, to whom the suggestion of aiding in the establishment of this Fund has been made by members. One member has already forwarded sixteen subscriptions of $100 each. All subscriptions will be acknowledged and published as provided for in the circular of January 1st, 1881.

To reduce the interest account, and to enable the Society to devote its funds more entirely to its publications, and other suitable purposes, additional subscriptions are desired, and you are requested, as in previous circulars, to bring the subject to the attention of persons interested in Engineering, and who might probably be very willing to become subscribers to the Building Fund, and receive the Transactions of the Society, if the subject was presented to them.

Respectfully,

JOHN BOGART,

Secretary Am. Soc. C. E.

The Secretary also reported the preparation of the following circular, the issue of which was authorized :

AMERICAN SOCIETY OF CIVIL ENGINEERS,
127 EAST TWENTY-THIRD STREET,
NEW YORK, ... 188 .

Mr. . . . . .

Sir,—Under the provisions of the circular issued on March 1st, 1881, the subscriptions to the Building Fund of this Society become binding when $10,000 shall be subscribed.

The subscriptions now amount to $10,600. You are therefore requested to forward the amount subscribed by you, either in two instalments or in one payment, as may be convenient. If made in two instalments, the first half should be sent directly, addressed to the Secretary, in draft or money orders made payable to the Treasurer of the American Society of Civil Engineers; the second half to be paid at your convenience on or before July 1st, 1881.

The amount subscribed by you was $.....

Respectfully,

JOHN BOGART,

Secretary Am. Soc. C. E.

The Secretary reported in full the transactions connected with the purchase of the property No. 127 East Twenty-third street, including the report as to title by the legal advisers of the Board, and the execution of the requisite papers by the designated officers of the Society. The Board approved the action thus taken.

Action was taken as to bank deposits and checks. The Finance Committee was requested to consider the question of a proper sum for compounding the annual dues now payable by members of the Society by the payment of such sum for constituting a life membership. Appropriations were made.

MAY 23D, 1881.—Arrangements for the 13th Annual Convention were considered.

MAY 25TH, 1881.—Arrangements for the 13th Annual Convention were made. The following was adopted as to invitations to the Convention:

Resolved, That invitations be extended to the families of members; that the Committee on Convention be empowered to invite individuals eminent in the profession, and editors of professional papers, and that the local committee at Montreal be requested to extend invitations at their discretion.

Resolved, That the Committee on Convention be requested to invite to the Convention the officers of Engineers' Societies, of the American Institute of Mining Engineers, and of the American Society of Mechanical Engineers.

Action was taken in reference to the investment of the Fellowship Fund. Applications were considered. Appropriations were made.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—June, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

THIRTEENTH ANNUAL CONVENTION OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

HELD IN THE CITY OF MONTREAL ON THE 15TH, 16TH, 17TH, AND 18TH OF JUNE, 1881.

FIRST SESSION—RECEPTION.

On the morning of Wednesday, the 15th, the Convention assembled in Molson Hall, McGill University.

Mr. JOHN BOGART, the Secretary of the Society, called the meeting to order, and said :

I am requested to open the Thirteenth Annual Convention of the American Society of Civil Engineers, and to say that we will be welcomed to the City of Montreal by His Worship the Mayor of the City. Previous to that, however, in accordance with the law of the Society, a Chairman of the Convention is to be elected from among members, not officers, of the Society ; and in accordance with the custom, the local committee at Montreal have nominated as Chairman Mr. THOMAS C. KEEFER, and I now have much pleasure in presenting that nomination to the Convention.

The nomination was unanimously ratified, and Mr. Keefer took the Chair.

The Chairman.—It is proper, gentlemen, that the first words of welcome should be spoken to you by the only gentleman who is authorized to speak for the whole of the citizens of Montreal. I regret to say that his Worship the Mayor, who has come here with great difficulty, is unable, through illness, to perform that duty himself, but he has brought a substitute who will assure you of a hearty welcome to the city over which he presides.

Mayor Beaudry.—Mr. President and gentlemen of the American Society of Civil Engineers, allow me to congratulate you upon your presence in the City of Montreal, and to welcome you and offer you the freedom of the city. I regret that I am unable to read the address which expresses so truly the sentiments I entertain in regard to your visit. It will be read to you by my son-in-law, who is also the city attorney of Montreal. I beg to introduce to you Mr. Roy.

Mr. Roy read the following address:

Address of the Hon. J. L. Beaudry, Mayor of the City of Montreal, to the President and Members of the American Society of Civil Engineers, in Convention assembled at the Wm. Molson Hall of McGill University, on Wednesday, the 15th of June, 1881.

Mr. President and Members of the American Society of Civil Engineers:

I have the honor, in the name of our citizens, to welcome you and to offer you the freedom of this our City of Montreal. I believe it is the custom of your Society to hold a convention annually in some of the principal cities of the continent, and this is, I believe, your thirteenth, and the first one held outside of the limits of United States territory. I was about to say, your own country, as was recently remarked by one of our city newspapers in commenting upon your expected visit, but I will not make use of that phrase myself, because I think that, as engineers, men who are intimately identified with all the great enterprises which unite not only territories, but continents, in the great march of civilization and progress, it should not be said that you are not in your own country, merely because you have crossed the line which divides two distinct political governments. I am sure that the American engineer never feels out of his country in pursuing the objects of his noble profession; at all events, he need not feel so, while he is in this Canada of ours; the lines that mark differences in political institutions are obliterated in these pursuits; besides, are not the arms of your Society extended open to your professional brethren on this side of the line, and have we not, as citizens of Canada and in this city, men who are members of your honorable body, and to whom the privileges and honors of your institution are extended as fully and as freely as to those who live under the American flag. Your brethren here, I am very certain, do not look upon you as strangers out of your own country, but

they are, as you are yourselves, all members of one body that knows no difference in creed or nationality ; and the Montreal members must feel gratified in being the cause, as I have no doubt they are, of the honor of this distinguished visit to our city. In connection with this visit, my attention has been particularly drawn to the importance of your Society as an institution, and I have to offer you my humble congratulations on the aims and objects for which it exists. I have glanced over the subjects which claim your thought and study, and the manner in which, in your discussions, those subjects are treated, shows me how you probe and burrow for the truths of practical life, and prompts me to increase, if that were possible, my admiration for the noble profession of civil engineering ; that profession whose object, it has been truthfully said, is the improvement of everything it touches for the use, economy and convenience of man. It is to your profession, Mr. President and gentlemen, that we are indebted for the great highways of commerce that stretch far and wide over the continent from the Atlantic to the Pacific ; that has shortened the once almost trackless ocean between two great commercial worlds to a mere bagatelle of a trip ; that brings those magnificent ships to our harbors ; that has laid hold of the lightning and used it to link the whole civilized world in instantaneous communication ; that pierces our mountains to let the iron horse go through, and that bridges our rivers so that even our great St. Lawrence offers no obstacle to the transportation of our merchandise and our products at all seasons of the year. And I am aware that, in the intelligent assemblage which I have now the privilege of addressing, there are men who have done these things, and who are capable of doing and will do still greater than have yet been done ; minds which have conceived and carried to successful completion many of those bold projects, in the interests of commerce, which have astonished the world and won the admiration and gratitude of their fellow-citizens, and have brought honor to their country. It is to your profession also that we are indebted for many of the conveniences, comforts and even luxuries of daily life ; usefulness to your fellow-men, is your great aim, and many of you have placed your names high up on the roll of fame, both in this and the mother country, for your achievements in your art. It is, therefore, an honor to our city that, by an almost unanimous vote, you have selected her as the place for this meeting.

With regard to what we have to offer for your entertainment, I regret that we have not very much to show of that which is most interesting to you. The Victoria bridge and the workshops of the Grand Trunk Railway Company are worthy of your inspection ; the harbor also may present a feature of interest to you ; and, on behalf of the city works, there are the Water Works and the Mount Royal Park.

In conclusion, Mr. President and gentlemen, let me say that, although our city lies far north, the hearts of our people are warm, and, on behalf

of the citizens, accept my best wishes for your enjoyment here, and for the success of your meeting. And I hope that this will not be your last convention here; I also hope, on behalf of our Canadian engineers who are not members, that they will take advantage of the privileges your institution offers to them, and that the Canadian membership will augment, for we cannot shut our eyes to the fact that union of men, particularly in such noble pursuits as those of your calling, must tend largely to cement the friendly feeling which exists generally between the inhabitants of both sides of the line which separates our governments. Again, Mr. President and gentlemen, let me heartily welcome you and tender you the freedom of the city.

I have the honor to be,

J. S. Beaudry,
Mayor.

The Chairman then introduced

Mr. Henshaw, President of the Montreal Board of Trade, who said:

When I had the honor of an invitation to meet this distinguished body, I had no idea that I was to be other than a silent spectator, and a very pleased one, of the proceedings of to-day. Had I imagined I should be called upon for anything in the way of a speech, I should have followed the example of our worthy Mayor, and made some little preparation for it. Occupying, as I do, the position of President of the Montreal Board of Trade, I cannot do less, certainly, than to welcome most heartily to this city so distinguished a body of gentlemen as have favored us with their presence. I have occasionally heard it remarked: "What practical good does a visit, such as this, do to a place?" I felt a pity for those who proposed such a question. For my part, I think the peculiar circumstances under which a visit of this kind is made, ought to be welcomed by the city with the greatest pleasure possible. The Civil Engineers are a class of men who are closely identified with the commercial interests of the whole world. They are naturally interested in, and competent to speak upon, railway lines, canals, and, in fact, every channel of intercourse between the west and the ocean through which commerce must pass, and, I think, under the circumstances, Montreal has been very highly honored by the presence of these gentlemen. I hope that the merchants of Montreal, and the citizens generally, will extend to them during their stay all the attentions they possibly can. We are particularly favored, also, by the presence of a large number of ladies who accompany the members of the society, and I trust they will receive such impressions of the city that we shall have the pleasure of seeing them again. In the name of the Board of Trade of Montreal, gentlemen, I offer you our warmest welcome.

The Chairman.—I now introduce to you another member of the Board of Trade, who is also a member of the Dominion Parliament, Mr. Thomas White.

Mr. White.—I confess, Mr. Chairman, that I am very much surprised, indeed, at this summons, for, although a member of the Council of the Board of Trade, in the presence of our President, I think no one else should speak in their name. I cannot, however, do otherwise, as a citizen of Montreal, than very cordially to express my own gratification at the presence of so distinguished a body in our city, and to extend to you the heartiest possible welcome on the part of the citizens of Montreal. There is, perhaps, no city on the continent more interested in works to which your minds are specially directed, than is this City of Montreal at the present time. The charts on each side of this room indicate some of the works upon which the success and prosperity of Montreal depend, and upon the successful carrying out of these works, I believe, will very largely depend the future of our city. I sincerely trust, gentlemen of the American Society of Civil Engineers, that your stay in Montreal will be not only a pleasant one, but a profitable one in affording you an opportunity of seeing those works upon which the city has so far depended for its prosperity in the past, and those works which we are now entering upon. There is no class of men, no department of industry, or intellectual labor, upon which the future of the country, and even of this whole continent, so largely depends as upon the profession represented here to-day. If to-day we have railways extending over every part of this vast continent, we owe it to the skill, to the foresight, to the indomitable industry of the department of civil engineering. If to-day we have great water highways which afford means of communication for the traffic and business of the country, we owe it to that same department of labor. I sincerely congratulate the City of Montreal that it has been selected for the place of meeting of so distinguished a body of gentlemen. I have the honor again, gentlemen, to welcome you most heartily on behalf of the city, and to express my earnest hope that your visit here will be one which, when looking back upon it in the future, you will have no reason to regret.

Mr. Mitchell, President of the Montreal Corn Exchange, said: When I came here I hardly expected to be called upon to speak, but I am glad to say that I heartily concur in what has been said by my friends of the Board of Trade, in welcoming the distinguished visitors we have with us. I wish the society that has so kindly favored us with this visit, every enjoyment during their stay here. I am sure that the association for which I speak welcomes them most heartily to Montreal, and unites with me in wishing them every enjoyment while sojourning in our city.

The Chairman.—It is now my pleasant duty to present to you a gentleman who requires no introduction from me, a gentleman whose reputation is trans-Atlantic as well as cis-Atlantic, Principal Dawson, the distinguished geologist, who is the President of this University, and to whom we are indebted for the use of the hall in which we are assembled.

Principal Dawson.—I do not know that it is necessary for me to add words of welcome to those that have already been spoken, but I may say one word on behalf of the University which I represent here. I must say that it gives us very great pleasure, and we regard it as a very high honor, to be able to entertain within our walls the distinguished Society which meets here to-day. McGill University, in some respects, perhaps, has a claim on the profession of civil engineering because it was the first university in this Dominion to recognize that profession as a learned profession, and to establish a professorship and a course of study in connection with this branch of knowledge. We did it as far back as 1856, and for the last twenty years nearly, our young men have been going out more or less prepared for active duty on the public works of this country and its engineering enterprises.

That our action in this respect has been a wise one, is borne out by the growth of our engineering department, now united with the other professions of mechanical and mining engineering in our faculty of applied science, and by the public support which the effort has secured. The work of the engineer, based on scientific principles, and carrying out those great enterprises of construction, almost of creation, is undoubtedly one of the highest connected with the material advancement of nations. The engineer is, in truth, at once the missionary and the pioneer of material civilization in its extension into new fields, and as was very well stated in the address of the Mayor, he is the organizer of the means whereby the larger and denser communities of men can exist with comfort, can be supplied with the necessaries and luxuries of life, and can hold communication with each other. Without the structures which he plans, rears and maintains, the fabric of our modern civilization would fall asunder, and its political, social and commercial arrangements would disappear like a dream. We do well, therefore, to welcome you as representatives of this great and honorable profession, and of the science and culture which its achievements represent, and to throw open to you whatever we have in books, collections or other objects of interest.

Not being an engineer, I cannot refer to those works in which you are professionally interested, but as a geologist, I may introduce you to the ancient and venerable foundations on which our city stands, and which may afford a field for the exercise of the profession of civil engineering. The lower Silurian Limestone of the Trenton age, which underlies a great part of the Island of Montreal, though originally a congeries of organic fragments of shells and corals, has nevertheless attained to the hardness and density of marble, and is our chief material of construction, along with its companion beds, the Chazy and Black River limestones. That is our great substratum here in Montreal, and constitutes the material for our great works of construction, and that out of which all our best buildings are built. These limestones may well be seen in the extensive quarries near the city. The next formation in

ascending order is the thick and soft Utica shale, dipping gently to the south towards the country from which you come. Though soft and comparatively useless, it has nevertheless permitted our noble river to excavate that channel which you see represented on the wall, because rivers, like engineers, select the softest material for their work, and one which they can most easily excavate. That Utica shale, also, is the material in which our engineers expect to build this tunnel which you see represented on the wall, and which is to bind us, along with the Victoria Bridge, to the south shore of the St. Lawrence. We are also indebted to that Utica shale, crumbling and soft, for much of the fertility of the soil south of the river, from which much of the food supply of this city is derived. Then we have here to the north of us that mass of rock, Mount Royal, not great as a mountain, but great in relation to Montreal, a mass of igneous rock of Dioritic and Syenitic character, which, in old times has burst up through this Trenton limestone and Utica shale, and now lifts it head above our city. It affords the beautiful ground for our Mountain Park, and serves also the more homely use of supplying material to macadamize our otherwise bad and dusty streets. Dr. Hunt and Dr. Harrington have worked out much of the chemical and microscopic characters of this great and varied mass. In regard to that mountain, I am reminded by the chairman that we should value it more than we do at present if we could calculate how much it would have cost to put it there. Associated with the mountain in origin is the patch of volcanic breccia on St. Helen's Island, a remnant of the ancient cone of the Montreal volcano, and which, by its being associated with the fossils of the Upper Silurian age, fixes the age of the chief eruptions of our mountain. Lastly, in the much later Ledea clays and Saxicava sands of the Pleistocene age, overlaying the older formations, we have the materials of our durable, if not very beautiful, red bricks ; and in them the geologist can collect abundant specimens of marine shells, identical in species with those now living in the northern part of the Gulf of St. Lawrence, and indicating the submergence of our country under the cold waters of the Arctic sea in that age known as the Glacial period, and in which the imagination of certain extreme theorists would have us believe that our continent was covered with a mantle of solid ice. Montreal now profits by all these preparations of past geologic ages, and, having passed out of its Glacial age, can now welcome you to a summer clime, a rich vegetation, and the hospitality of a growing, if not yet great city. In conclusion, allow me to say, that the University, in offering the use of its hall to this society, also offers you all the conveniences and arrangements in connection with it ; the library and the museum rooms will be entirely at your service during your sojourn here, for we wish to do everything in our power to make it both pleasant and useful to you.

Vice-President Welch, at the request of the President of the Society, responded on behalf of the Society as follows :

Mr. Chairman,—The worthy Mayor used one expression which runs against all my former conceptions. He spoke of the American Society of Civil Engineers in Montreal being out of their own country. Why, I thought Canada was in America ! It does not make any difference whether some members of the society acknowledge as their Chief Magistrate the illustrious man who lives in the White House at Washington, while other members acknowledge as their sovereign that glorious woman whom we all love—not because she is Queen of Great Britain and Ireland and Canada—not because she is Empress of India—not because she rules over one-quarter of the human race, and that the best quarter—but because she realizes and exemplifies this sentiment :

> "The rank is but the guinea's stamp,
> The man's (or woman) the gowd, for a' that."

We feel that she's the "gowd." I say it does not make any difference which of the two we acknowledge as our Chief Magistrate, we are all Americans, and in the simplicity of my heart I thought the American Society of Civil Engineers embraced Canada as a matter of necessity. But, Mr. Chairman, this welcome, and one or two other welcomes to Canada that I have witnessed, remind me of a great contrast. In 1812 some Americans came over to a small place then called Little York, now the magnificent city of Toronto. Well, we were welcomed on that occasion by bayonets, bullets and grape shot, and we returned what they gave. Now, we have just heard these warm words of welcome, words used, I doubt not, in all sincerity, judging from our own feelings, because we attribute the same feelings to our fellow-citizens—I mean our friends—of the City of Montreal. We have heard of the great material benefits civil engineers have conferred upon this city—upon every part of the continent, and upon mankind. But that is not the highest object attained by the civil engineer. He has made the bonds that unite the North and South of the United States. Those bonds have healed the dissensions and mitigated the hostility that unfortunately existed at one time between those two sections. I believe that the railroads connecting North and South have done more than any other cause, except religion, to harmonize those sections of our common country. And so it is with other countries. Canada and the United States are now practically one people, though under different governments. That engineer has a very inadequate conception of his mission who considers that material good, commercial good, is the highest end of his profession. The real and highest result accomplished by the engineer is by the works he constructs, the railways, the telegraphs and

the steamships by which he unites the distant regions of the whole world, to assimilate, to civilize and to Christianize the human race.

The reception being ended, the Convention proceeded to the business of the day.

The Secretary made an announcement concerning the entertainments provided by the Local Committee.

A paper by L. L. Buck, M. A. S. C. E., subject, "The Re-enforcement of the Anchorage and the Renewal of the Suspended Structure of the Niagara Railway Bridge," was, in the absence of the author, read by the Secretary.

The Secretary announced that the Department of Railways and Canals at Ottawa had sent to Montreal, for the use of the members of the Convention, 100 copies of the last report of the Chief Engineer, containing illustrations of Canada's public works; also, railway maps; and, through Colonel Denis, of the Department of the Interior, 100 maps of those portions of the Northwest Territory opened up by the Canadian Pacific Railway.

Mr. Sanford Fleming, M. A. S. C. E., then read a paper, subject, "Uniform Standard Time for Railways, Telegraphs and Civil Purposes Generally."

A recess was then taken, during which occurred the drive to the Mountain Park and the garden party at the residence of Mrs. Redpath.

Evening Session, June 15th.—On the Convention reassembling at 8 p. m.,

The Chairman read a letter from the Managing Director of the Grand Trunk Railway, offering a special train for the conveyance of the members to Quebec; also, a letter from the Art Association of Montreal, extending an invitation to the Society to visit the Art Gallery; also, from the Secretary of the Mechanics' Institute of Montreal, inviting the Society to visit the library and reading-room; also, a telegram from Mr. Collingwood Schrieber, Chief Engineer of the Intercolonial Railway, offering free passage to members of the Convention wishing to visit the Maritime Provinces.

The Secretary made several announcements regarding the local programme, and stated that he had received a telegram from Mr. Benjamin Rhodes, Engineer in charge of the upper Suspension Bridge at Niagara Falls, tendering an invitation to the Society to hold its next Convention at that place.

The President, James B. Francis, then read the Annual Address, which will be printed in the Transactions.

On the suggestion of the Secretary, the Convention then proceeded to the consideration of Mr. Fleming's paper on "Standard Time for Railways and Telegraphs."

On motion, the following committee was appointed, with power to add to their number, to whom the paper presented by Mr. Sanford Fleming was referred for consideration and report: Sanford Fleming, of Ottawa, Canada; Charles Paine, of Cleveland, Ohio; A. J. Cassatt, of Philadelphia, Pa.; J. M. Toucey, of New York, N. Y.; J. E. Hilgard, of Washington, D. C.; T. Egleston, of New York, N. Y.; T. G. Ellis, of Hartford, Conn.

The paper on the Re-enforcement of the Anchorage and the Renewal of the Suspended Structure of the Niagara Railroad Bridge, by L. L. Buck, was then discussed by Messrs. A. P. Boller and E. S. Chesbrough,

A paper by O. Chanute, Vice-President of the Society, subject. "Repairs of Masonry," was, in the absence of the author, read by the Secretary, and discussed by members present.

Mr. J. J. R. Croes, for the Committee on the Engagement of Civil Engineers upon Government Works, presented the following report:

To the American Society of Civil Engineers, New York, June 14, 1881:

At a meeting of the Society, held during the Twelfth Annual Convention, at St. Louis, the following resolution was adopted:

"*Resolved*, That a committee of seven be appointed to prepare a memorial to Congress, asking that Civil Engineers may be placed in full charge of the works of public improvement carried on at Government expense, such memorial to be submitted to the Society, and voted on by letter ballot on the first Wednesday in November."

The committee appointed under the provisions of the above resolution beg leave to submit the following report:

It will be observed that the resolution under which this Committee was appointed specifies that the form of memorial reported by the Committee shall be submitted to the Society for letter ballot. This would seem to imply that the Society as a body shall be asked to accept the memorial, and present the same to Congress.

Your Committee, after maturely considering the subject, have thought it advisable to suggest that it may be inexpedient for the Society to place itself in the position of advocating before Congress the claims of a certain class of its membership, in seeming conflict with any other class whose interest may be in a different direction.

Your Committee have not lost sight of the fact that a large majority of the members of the Society are engineers practicing in civil life. Nevertheless, it must be borne in mind that some of our most prominent colleagues are, or have been, military engineers in the sense referred to in the memorial, and it may very well be questioned whether the Society, as a body, should commit itself to a line of action which might be construed as in the least inimical to the professional interests of any of its members.

The objects for which the Society was instituted are clearly defined in Articles II and III of the Constitution, which read:

"ART. II. Its object shall be: The professional improvement of its members, the encouragement of social intercourse among men of practical science, the advancement of engineering in its several branches, and the establishment of a central point of reference and union for its members.

"ART. III. Among the means to be employed for attaining these ends shall be periodical meetings for the reading of professional papers, and the discussion of scientific subjects; the foundation of a library; the collection of maps, drawings and models; and the publication of such parts of the proceedings as may be deemed expedient."

From all of which it would appear that, while the professional improvement of its members is to be considered as a prime motive, there should never be the least appearance of an attempt at discrimination in favor of a particular class of membership to the detriment of others.

Your Committee have acted upon this view in preparing the memorial.

It is intended to be an expression of opinion of such civil engineers as may sign and present it to Congress in furtherance of their own interests, and the Society may with propriety decline to consider the subject further.

The Committee respectfully request that they be discharged.

CHARLES MACDONALD,
J. J. R. CROES,
T. C. CLARKE.

[Form of Memorial.]

To the Senate and House of Representatives of the United States:

Your petitioners, citizens of the United States, and civil engineers by profession, beg leave to call your attention to the fact, that the civil engineering works now carried on by the General Government, such as the improvement of harbors and rivers, explorations and surveys for the extension of agriculture and commerce, etc., although they employ in positions of responsibility and trust a large number of civilians, are superintended, with one or two exceptions, exclusively by officers of the Corps of Engineers of the Army.

The number of such works is greater than the number of experienced officers who can be detailed to take charge of them, in addition to their other duties in the construction and maintenance of our national defenses.

Consequently, most of these works are practically in the hands of civilians, although occupying subordinate positions, and many of the most experienced civil engineers in the country, who are well fitted by skill and education to take principal charge, are unwilling to accept such positions, where neither adequate emolument nor reputation can be hoped for.

Your petitioners therefore pray that such legislation may be had as shall admit of the direct employment of civil engineers upon Government works in such positions as they may be competent to occupy, and shall put the civil and military engineers of the United States upon a common footing in regard to the execution of national public works not of a military character.

On motion, the report of the Committee was accepted and the Committee discharged.

The Convention then took a recess.

VISIT TO OTTAWA.

June 16.—In the morning the members of the Convention embarked on a special train of the Q., M., O. & O. R.R., placed at their service by the Local Government of the Province of Quebec, and proceeded to Ottawa, the Capital of the Dominion, distant 115 miles from Montreal. At Ottawa they were received at the railway station by Sir Leonard Tilley, Finance Minister of the Dominion, the Hon. Mr. Caron, Minister of Militia, and by a local Reception Committee, whose names are given hereinafter. The party having visited the Chaudière Falls, and inspected the extensive saw mills situated there, made the descent of the timber slides upon cribs of squared timber which had been prepared for this purpose, and then drove to the Union House, where they were entertained with a collation. The following letters were received by the Secretary of the Committee.

From Sir H. L. Langevin, Minister of Public Works for the Dominion of Canada:

W. B. Smellie,
C. E., Ottawa:

My Dear Mr. Smellie,—I would have been very happy to avail myself of the kind invitation from the Reception Committee, thereby showing my appreciation of the visit to Ottawa of the body of American engineers; but, unfortunately, I had previously made an engagement which it is impossible for me to cancel. I am convinced that these gentlemen will receive at your hands every attention to which they are entitled and so honorably deserve, and that they will carry back with them a good and memorable souvenir in favor of our Canadian Capital.

Yours very truly,

Hector L. Langevin.

From the Hon. D. L. Macpherson, Speaker of the Dominion Senate:

Mr. Macpherson regrets that a previous engagement will prevent his having the pleasure of assisting at the reception of the American Society of Civil Engineers this afternoon.

Ottawa, 16th June, 1881.

From the Hon. J. A. Mousseau, President of the Council of the Dominion:

Ottawa, June 16th, 1881.

W. B. Smellie, Esq.,

Engineer, Ottawa:

My Dear Sir,—It is only this morning that I had the honor to receive your invitation to attend the reception of the American Association of Civil Engineers, at 1 o'clock p. m. to-day. I am sorry previous engagements make it impossible for me to shake hands with the American and Canadian Engineers, who in this time of railways and canals, are the true pioneers of civilization, because they foster progress, prosperity, and international intercourse amongst the various nations in the world.

Most truly yours,

J. A. Mousseau.

Mr. C. H. Mackintosh, Mayor of Ottawa, presided at the collation. The first toast proposed and honored was that of "The Queen." The next toast was that of "The President of the United States."

The Hon. J. Q. Smith, Consul-General of the United States in Canada, in response, said: "Mr. Mayor, Ladies and Gentlemen—A few minutes before we came into this room it was intimated to me that there would be a toast to the President of the United States to which I would be expected to respond. I expressed the opinion to the gentleman who conveyed that intimation, that it was an improper time to make speeches, and he replied, "The shorter the better." I shall, therefore, say just as few words as I consistently can in grateful acknowledgment of the toast to the President of the United States. I apprehend there is a sort of double duty about it. In the first place, I have to thank the people of Canada, and particularly the people of Ottawa, on behalf of the President of the United States, for receiving the American Society of Civil Engineers so kindly; and in the second place, as a temporary resident of Canada, I have to congratulate the Society of Civil Engineers upon the heartiness of their reception in Canada. When I first came to Canada I was asked almost every other day what the people of the United States thought of Canada. Well, I think Canadians are finding out pretty well what the people of the United States think of them by these frequent visits of distinguished societies from the United States to Canada. I am very sure, gentlemen, that the people of the United States who visit Canada will carry back with them a very vivid impression of the kindness and hospitality of the people of Canada. I thank you for the compliment you have paid the President of the United States.

The toast to the Governor-General and the Princess Louise having been honored,

The Mayor.—I have reason to regret that some more eloquent tongue, some more intellectual mind was not chosen on this occasion to propose the important toast that I am about to propose. I feel myself inadequate to the occasion, and for this reason I asked Mr. Bogart to announce to you that we were in a great hurry. The tokens of honor, ladies and gentlemen, the respect with which your profession has been received are proof positive that we are on the march of civilization, that we are making progress. Men are coming to recognize all professions as honorable in proportion as they depend upon the exercise of high human intelligence. We know what you have accomplished on the other side of the border, and you know what we are accomplishing in our younger and less developed country. I can assure you, gentlemen, that Canadians are proud of our civil engineers who are among us, and who are your hosts to-day. We are proud of Mr. Fleming, who, on the Canadian Pacific, and on the Intercolonial, has proved himself a competent and able engineer. We have here, ladies and gentlemen, Mr. Keefer, whose name, like Mr. Francis' name in the United States, is a household word in Canada. We have here Mr. Walter Shanley, and you who know what the Hoosac Tunnel is can form some idea of Mr. Shanley's engineering capacities. We know you to be an able class of engineers. We know you as hydraulic engineers, we know you as mechanical engineers, and as civil engineers, but it has remained for you to learn to-day that we have a class of engineers that I don't think you can surpass, and that is our "Crib Engineers."* Ladies and gentlemen, I have always heard that the associations from the other side of the line, when they come to Canada, always behave very well, and I have always observed that when they get that credit they always have their wives and sisters with them. The present occasion abundantly bears out the rule, and I congratulate you upon it. I can only hope that this visit to the Capital of Canada will be productive of a continuance of that harmony that already exists between the two nations. I can only hope that we may all be able to sing "Yankee Doodle"—though my friend, President Francis, says he does not like it as well as the "Old Suwanee River" song—in the words of somebody whom I once heard sing it:

> "Now let us strive these bonds to knit,
> And in the work be handy,
> That we may blend 'God save the Queen'
> With 'Yankee Doodle Dandy.'"

Now, gentlemen, I only hope those days will come, and that harmony, peace and good-will will always exist between the two nations. We are all jointly interested in solving the problem of national progress on this side of the Atlantic, and I believe that on this side of the Atlantic now

* Referring to the cribs of square timber which had been floated down the slides at the Chaudière Mills.

exists the greatest confederation of freemen that ever existed under the sun. I, therefore, ladies and gentlemen, without any further comment, beg to propose the toast of "The President and members of the American Society of Civil Engineers," coupled with this I will call upon General Ellis and Mr. Bogart to respond.

General T. G. Ellis.—Since you have called upon me to respond for the American Society of Civil Engineers, I will say that when Montreal was proposed last year as the place of meeting for our Convention, it was with a great deal of doubt that I acquiesced in going to a foreign country. I was a little afraid that the invasion of a Society like this into a foreign country might be regarded in a little different light from what we intended. But when we arrived at Montreal and met with such a kind reception, when we were carried around the mountain to see that delightful view, and were received so hospitably by all whom we met, my doubts entirely vanished. I began to feel that we were all Americans; that the people of the United States and the people of Canada were in sympathy with each other; that though they might be under different governments they were really all Americans. We are all on the same side of the water, and we assimilate and associate together as one people. And when I came up here to Ottawa and saw the beautiful scenery along the railroad, and observed the extensive lumber manufacture, I thought then also that we were all Americans. I see here the same spirit of enterprise and development that I see in the United States. And when I visited the Chaudière Mills and witnessed that hydraulic experiment in rafting lumber down the slides, I thought that in some respects, at least, the engineers of Canada were greatly in advance of the engineers of the United States. Previous to seeing that experiment I do not think there was an engineer in our Society who would have volunteered to carry those rafts safely down those rapids, but I think now we could all do it. We have learned something. And, gentlemen, let me say in conclusion that whenever any engineer or any resident of Canada, any person bearing the devices that we see around this hall, any person who calls himself a Canadian, shall come to the United States, we shall receive him with as warm hearts and as open arms as you have received us here to-day.

Mr. J. Bogart then made a few remarks.

The Mayor.—Prior to leaving for Parliament Hill the corporation of Ottawa desires to present to your diffident President and the diffident members of your Association a short address, which I will now read:

Mayor's Office,
Ottawa, June 16, 1881.

To the President and Members of the American Society of Civil Engineers:

Gentlemen,—On behalf of the corporation we welcome you to the Capital of the Dominion, and only regret that the pressure of your en-

gagements precludes the possibility of a more tangible manifestation of regard and appreciation.

The splendid engineering triumphs achieved by you and those you represent throughout the United States ; the record of active, indomitable zeal and intellectual exertion, productive of such wonderful progress is stamped upon every page of your country's history, whilst the practical results will ever remain as monuments commemorative of the intelligence and civilization which mark the nineteenth century.

Be assured that we are not unmindful of what Canada owes to those who have set so noble an example in the field of scientific research, and we shall ever retain a kindly and generous sentiment towards the distinguished visitors present in Ottawa to-day.

Signed in behalf of the corporation.

C. H. Mackintosh,
Mayor.

W. P. Lett,
City Clerk.

The Mayor, after reading the address, presented it to Mr. Francis, President of the Society, who said:

On behalf of the American Society of Civil Engineers I beg to present to you their hearty thanks for your hospitable reception. We hope to see any or all of you in the United States.

The company then proceeded to inspect the Parliament buildings and the city water works, after which they re-embarked for Montreal where they arrived shortly after 10 o'clock.

Friday, June 17th.—The Convention resumed business at 10:30 a. m.

The Chairman suggested the propriety of appointing a committee to draft an address in reply to the address presented to the Society at Ottawa yesterday, and which bore the official seal of the corporation of Ottawa, and also an address in reply to that presented by the Mayor in behalf of the corporation of Montreal.

On motion, the Chairman was requested to appoint a committee for that purpose.

The Secretary read a telegram from Atlanta, Georgia, inviting the Society to take part in the Exposition to be held there during the three last months of the present year.

On motion, the Secretary was instructed to acknowledge the receipt of the telegram and to present the thanks of the Society therefor.

A paper by Ashbel Welch, Vice-President of the Society, subject "Comparative Economy of Light and Heavy Rails," was then read by the author.

A recess was then taken during the business meeting (see page 62).

At the close of the business meeting the session of the Convention

was resumed, and the following Nominating Committee was appointed in accordance with section 24 of the by-laws:

Wm. E. Worthen, of New Nork; John Kennedy, of Montreal, Canada; John MacLeod, of Louisville, Ky.; A. F. Wrotnowski, of New Orleans, La.; M. Lane, of Milwaukee, Wis.

A recess was then taken.

In the afternoon an excursion was taken upon the river in a steamer provided by the Harbor Commissioners. After a sail along the city front, the lower lock of the Lachine Canal was visited and the operation witnessed of putting into position one of the new lock gates of the enlarged canal. The steamer then passed through the canal to the Wellington basin.

A special train upon the Grand Trunk Railway was then taken, and the Victoria Bridge visited and examined Afterward the train took the party to the extensive shops of the Grand Trunk Railway. All the mechanical departments were inspected under the escort of the officers in charge, and at the close of the inspection the library and reading room for the employees were visited. Here a handsome collation was provided, and addresses were made by members of the Society and by officers of the railway. Music was given by a band formed of employees of the railway.

The same train then took the party to the pumping station of the city water works which were examined in company with the engineers in charge of the water service.

In the evening a reception was given at the Windsor Hotel.

Saturday, June 18th.—The Convention reassembled at 10:40 a. m.

The Secretary made announcements.

The following resolution offered by J. J. R. Croes was adopted:—That the thanks of the American Society of Civil Engineers, in Annual Convention assembled, be returned to the several corporations, committees and individuals who have, by their kind feelings, courtesies and liberality, shown their interest in the Society and contributed so largely to the enjoyment of its members on this occasion, and that the Secretary be directed to communicate to each of the same a copy of this resolution.

A paper by Messrs. T. C. Clarke, John Griffin, A. Bonzano and David Reeves (Clarke, Reeves & Co.), subject, "Experiments upon Full Size Phœnix Columns," was read by the Secretary, and discussed by A. Coffin.

A paper by Robert H. Thurston, subject, "On the Strength and Ductility of the Copper-Tin-Zinc Alloys," was, in the absence of the author, read by the Secretary.

A paper on Systems of Sewerage, by R. Hering, was read by the author.

The Secretary—I have here several answers to a set of questions on

this subject which a member of the Society, Mr. J. J. R. Croes, prepared some time ago, and sent out to some of the members.

The Secretary then read answers to these questions and discussion on the subject which had been received from Messrs. W. R. Hutton, C. E. Fowler, Eliot C. Clarke, J. F. Flagg, and Louis H. Knapp.

The subject was also discussed by Messrs. C. E. Fowler, A. Merriwether, J. Bogart, T. G. Ellis, A. P. Boller, J. J. R. Croes and P. A. Peterson.

A paper on Weights and Measures, by C. Latimer, was then read by the author, and discussed by Messrs. A. Welch and F. Brooks.

Vice-President Welch announced, for the President, the following committee upon the subject of Tests of Iron and Steel: T. Egleston, A. P. Boller, T. C. Clarke, F. Collingwood, William Metcalf.

The Chairman announced the following Committee for drafting replies to the addresses of the corporations of Montreal and Ottawa: The President, the Vice-Presidents and Secretary of the Society, and Messrs. Wm. E. Worthen and T. G. Ellis.

The Convention then adjourned.

A large number of the members of the Society, *en route* to the Convention at Montreal, met at Niagara Falls on June 11th, the Saturday preceding the opening session of the Convention. During that day they fully examined the re-enforcement of the anchorage and the new suspended structure of the Niagara Railway Suspension Bridge. They were accompanied by Mr. L. L. Buck, Member A. S. C. E., who was the engineer in charge of that work, and by Mr. W. G. Swan, the superintendent of the bridge.

The roadway Supension Bridge near the Falls, was also visited, and the three recently built suspension bridges on the Canada side connecting the islands above the Falls. These were examined under the escort of Mr. Benjamin Rhodes, the engineer in charge of their construction. The new constructions of the water power company were also inspected. A visit was made to Lewiston, and to the wreck of the old Suspension Bridge near that place.

On Monday morning the party proceeded by the Great Western Railway to Toronto. At that city they were met by W. Gooderham, Jr., Esq., under whose escort a drive was taken through the city, visiting the station of the Toronto & Nipissing Railway, where the successful working of the Haggas Water Elevator for Locomotives was practically exhibited. After a drive through the park, and the grounds of the university, a reception was given to the members of the Society and its guests by Col. C. S. Gzowski, Member A. S. C. E. The party was welcomed by Col. Gzowski and family, and by the Lieutenant-Governor of the Province of Ontario. Short addresses were made on this occasion.

The journey from Toronto to Montreal was made by steamer on Lake Ontario, passing the Thousand Islands and the Rapids of the St. Lawrence, and arriving at Montreal on Tuesday afternoon, June 14th. A delegation of the local committee at Montreal met the steamer early on that day and returned with the party so as to assure every arrangement for their reception at that city.

The programme of the Convention was printed in a handsomely bound pocket-size form, with an appropriately illustrated cover. This printed programme was as follows :

AMERICAN SOCIETY OF CIVIL ENGINEERS.

Thirteenth Annual Convention—Montreal, June 15, 16, 17 and 18, 1881.

The headquarters of the Society during the Convention will be at the Windsor Hotel. The Secretary's office will be in Parlor No. 4.

The meetings of the Convention will be held in the William Molson Hall, McGill University.

Members of the Society and guests of the Convention will please report at the Secretary's office, in the hotel, immediately on arrival.

Special Committees for each day are designated in the programme, and will be known by a tri-color badge.

The Grand Trunk Railway, and the Quebec, Montreal, Ottawa & Occidental Railway, have kindly placed special trains at the disposal of the Convention for the excursions indicated in the programme.

Wednesday, June 15th.—Convention will be called to order at 9 30 A. M.; Hon. J. L. Beaudry (M. L. C.), Mayor of Montreal, will welcome the Society on behalf of the citizens of Montreal; the Board of Trade and Corn Exchange will assist in the reception; Principal Dawson (McGill University), C. M. G., will deliver an address.

Adjournment.—Lunch. In the afternoon, leaving the hotel at 1.45 o'clock, an excursion in carriages will be made to the Mountain Park, and Terrace Bank, the residence of Mrs. Redpath, who has kindly invited the Society to a garden party, from 4 to 6.30 P. M. At 8 P. M. the regular meeting will be held, to which the public are invited. The President of the Society, James B. Francis, Esq., will deliver the Annual Address.

Special Committee.—*C. S. Gzowski, *G. D. Ansley, Henry T. Bovey, F. R. Redpath, *R. J. Brough.

Thursday, June 16th.—Excursion to Ottawa. Leave the Mile End Station of the Q. M. O. & O. R. R. at 9.20 A. M., arriving at Ottawa at 1 P. M.; visit the Chaudière Falls, Water Works and Timber Slides; opportunity will be given to descend the latter upon cribs; dinner; visit the Parliament Buildings, Rideau Canal, etc., returning from Ottawa at 6.30 P. M., and reaching Montreal at 10 P. M.

* Are Canadian members of the Society.

Special Committee.—W. Shanly, *Samuel Keefer, *P. A. Peterson, *Sandford Fleming, *W. G. Thompson.

Friday, June 17th.—Session, 9–12. In the afternoon, leave the hotel at 1.30 and drive to the Island Wharf for an excursion upon the river in a steamer which has been kindly placed at the disposal of the Convention by the Harbor Commissioners. The boat will return at 2.30 P. M., when those who were unable to be present for the first trip may be taken on board at the lower lock of the Lachine Canal, and then pass up the canal to the Wellington Bridge Basin ; visit the Victoria Bridge, Grand Trunk Work-shops and the City Water Works ; return to Bonaventure Station at 6 o'clock.

Special Committee.—J. Page, *J. Kennedy, *E. P. Hannaford, H. Wallis, L. Lesage, E. H. Parent.

Society reception at the Windsor at 7.30 P. M.

Saturday, June 18th.—Session, 9–12.

List of illustrations : page 2—Boat approaching Rapids ; page 4—Victoria Bridge ; page 6—Port of Montreal (Summer) ; page 8—Port of Montreal (Winter) ; page 10—Ice Railway ; page 12—Lock, Lachine Canal ; page 14—Parliament Buildings, Ottawa ; page 16—Timber Slide, Ottawa ; page 18—Canadian Winter and Summer Scenery.

The City of Montreal.

On the second of October, 1535, Jacques Cartier landed about six miles below the current St. Mary, and was conducted with certain ceremonies into Hochelaga, now the eastern suburb of the City of Montreal. After having ascended the mountain which forms the beautiful background to the present city, Cartier gave it the name of "Mont Royal" in honor of the King of France, and, on his return to his native country, recommended it as a favorable site for a settlement.

The actual foundation of Montreal may be dated from the 17th of May, 1642, when Maisonneuve landed. His followers forthwith fell on their knees, and all joined their voices in songs of thanksgiving ; an altar was erected, mass was celebrated, and the officiating priest, under the shadow of Mount Royal, thus addressed the pioneers of the present city: "You are a grain of mustard seed which shall rise and grow until its branches overshadow the land." In the evening, Maisonneuve and his companions pitched their tents, lighted their fires, stationed their guards, and lay down to rest. Such was the birth-night of Montreal.

Exactly one century later, the site selected for the city was consecrated with due solemnities, commended to the "Queen of the Angels," and called "Ville-Marie," a name which it retained for a long period. In 1760, it was taken by the English. In 1764, the first newspaper in Canada was published in Montreal. In 1809, the first steam vessel made a trip from Montreal to Quebec; she had berths for 20 passengers. In 1836, the first railway in Canada was opened from St. Lambert's, oppo-

site Montreal, to St. Johns, and in 1847, the Montreal & Lachine Railway, the first railway on the north side of the St. Lawrence, was put in operation. In June, 1853, the Grand Trunk Railway was opened to Portland. In 1801, the first water works were erected in Montreal by a company. The water was supplied by gravitation through wooden pipes. In 1819, they were replaced by 4-inch iron pipes. In 1832, the works passed into the hands of another company, and water was pumped from the river in front of the city, into a reservoir on Notre Dame street. In 1849, a new reservoir was built 25 feet higher in another part of the city, which contained 208 000 cubic feet of water. Referring to this reservoir, a city newspaper remarks at the time: "The great altitude of this immense cistern will enable the committee to supply water to the upper stories of almost every house in town." In 1852, the plans for the present mode of supply by water power were submitted and adopted. The works have been enlarged with the growth of the city, and the pumping capacity is now 24 million imperial gallons per 24 hours—the daily consumption averages 10 millions, or 74 gallons per head; there are 133 miles of mains, 25 752 houses supplied, and 866 hydrants. The annual revenue from the water supply is $366 475.

The sewerage has a total length of 83½ miles.

The area of Mount Royal Park is 430 acres.

The population of Montreal is about 150 000, occupying an area of 3 630 acres within the corporate limits. Length of streets, 105 miles. Assessed value of real estate, $66 160 613, of which the property of the Government, churches and educational establishments, to the value of $13 964 050, is exempt from taxation. The total annual revenue of the city from all sources is $1 519 817. The rate of assessment is one per cent. on real estate, and for business taxes seven and a half per cent. on rental of premises.

Victoria Bridge.

First stone, No. 1 Pier, laid 20th July, 1854.

First passenger train passed 17th December, 1859.

Total length of bridge, 9 184 feet lineal.

No. of spans, 25; 24 of 242 feet; one of 330 feet.

Height from surface of water to underside of centre tube, 60 feet.

Height from bed of river to top of centre tube, 108 feet.

Greatest depth of water, 22 feet.

General rapidity of current, 7 miles an hour.

Cubic feet of masonry, 3 000 000.

Cubic feet of timber in temporary work, 2 250 000.

Cubic yards of clay used in puddling dams, 146 000.

Tons of iron in tubes, say 8 250.

Number of rivets, 2 500 000.

Acres of painting on tubes, one coat, 30; or for the four coats, 120 acres.

Force employed in construction during summer of 1858, the working season extending from the middle of May to the middle of November :

Steamboats, 6 ; horse power, 450 ; barges, 72		12 000 tons.
Manned by	500 sailors.	
In stone quarries	450 men.	
On works, artisans, etc	2 090 "	
Total	3 040 "	
Horses, 142 ; locomotives, 4.		
Total cost		$6 300 000

Test of Tubes.

A train of platform cars, 520 feet in length, and drawn by three engines, extending over two tubes, was loaded almost to the breaking limit of the cars, with large blocks of stones.

When the train covered the first tube, the deflection in the centre amounted to $\frac{7}{8}$ of an inch, and the adjoining one to which it was coupled, was lifted in the middle $\frac{3}{8}$ of an inch. The load then being placed over both tubes, the deflection was the same in each, or $\frac{3}{4}$ of an inch in the middle, and on being entirely removed, both sides assumed their original level.

The large centre span, entirely disconnected from the other tubes, on being covered with the load throughout its entire length, deflected in the centre $1\frac{7}{8}$ inches, and came back to its previous level on the load being removed.

CANADIAN WATERWAYS.

The Valley of the St. Lawrence.

This great basin covers an area of 400 000 square miles, exclusive of lakes and rivers, which, including the gulf, have an area of 130 000 square miles. About 70 000 square miles belong to the United States, leaving 330 000 to Canada, 280 000 of which is upon the north side of the St. Lawrence, embracing not only some of the finest agricultural and timbered lands, but also the great northern hill region, or Laurentian system, the oldest known rock formation of the globe, rich in iron, copper, lead, gold, silver, phosphates, plumbago, mica, barytes, asbestos, etc.

The great lakes, the largest and purest body of fresh water in the world, have an area of 90 000 square miles, with dimensions, depths, and elevations above tide, as follows :

	Length.	Breadth.	Depth.	Elevation above Sea.	Area in Sq Miles.
	Miles.	Miles.	Feet.	Feet.	
Superior	460	170	800	600	31 500
Michigan	330	90	700	576	22 000
Huron	260	110	700	574	21 000
Erie	250	60	200	565	9 000
Ontario	180	60	600	235	6 400

The calculated discharge from the upper lakes by the Niagara river is over twenty millions of cubic feet per minute, and as this does not represent more than half the rain-fall upon the drainage area of their basins, it is assumed that the evaporation is equivalent to the volume discharged by the outlets to the sea.

The Lakes of the Prairie Region.

The lake system of the prairie region is low in altitude, covers an area of 13 000 square miles, and is as follows :

Winnipeg	area	8 500	square miles	above sea	650	feet.
Manitoba	"	1 900	"	"	670	"
Winnepegosis	"	1 936	"	"	692	"
Cedar Lake	"	312	"	"	688	"
Dauphin Lake	"	170	"	"	700	"

The River System.

The four principal rivers on the eastern, northern and western watersheds of Canada are :

St. Lawrence,	length,	1 500	miles	drainage area,	330 000	square miles.	
Saskatchewan and Nelson,	"	1 500	"	"	450 000	"	
Mackenzie,	"	1 200	"	"	440 000	"	
Fraser,	"	450	"	"	30 000	"	

The Ottawa, a branch of the St. Lawrence, is nearly 600 miles in length.

Canals of Canada.

The canals of Canada are more remarkable for their breadth than for their length. The total length of canal and river improvement embraces about 250 miles upon the St. Lawrence, Ottawa, Rideau, and Richelieu Rivers, exclusive of the ship channel improvement below Montreal. The existing St. Lawrence canals have a bottom width of 80 to 100 feet, surface width 120 to 150 feet, with 10 feet depth of water, the locks being 200 feet long by 45 to 50 feet wide in chamber. The locks of the Wel-

land Canal are 150 feet in length by 26 feet in width of chamber, depth of water, 10 feet. Both these works are now in course of enlargement upon a uniform scale of locks 270 feet long by 45 feet wide, in the chamber, with a depth for vessels drawing 14 feet. The Welland will be opened with enlarged locks, but only 12 feet draught of water, next month.

From the Atlantic entrance of the Straits of Belle Isle *via* the River St. Lawrence and lakes, to Fond du Lac (head of Lake Superior), the distance is 2 384 miles. On this route there are the Lachine, Beauharnois, Cornwall, Farron's Point, Rapide Plàt, Galops and Welland Canal, the aggregate length of which is 70¾ miles, and the total lockage 536½ feet through 54 locks up to Lake Erie; also the Sault Ste. Marie Canal, 1 1/10 miles in length, with 18 feet lockage, uniting Lake Huron and Lake Superior.

The progress of improvements on the St. Lawrence is shown as follows: For the

Lachine Canal.

Boat Canal.—Formed last century *via* River St. Pierre to Montreal. Depth of water, 2½ feet.

Barge Canal.—Commenced in 1821, and completed in 1825. Cost, $438 404. Length, 8¼ miles; lockage, 44½ feet; bottom width, 28 feet, at water surface, 48 feet; 7 locks, 100 feet long, 20 feet wide, with 4½ feet depth of water on sills.

Ship Canal.—Commenced in 1843, and completed in 1849. Cost, $2 149 128. Length, 8½ miles; lockage, 44½ feet; bottom width, 80 feet, at water surface, 120 feet; 5 locks, 200 feet long, 45 feet wide, with 9 feet of water on sills.

Enlarged Ship Canal.

Commenced in 1875. Probable cost, $6 500 000. Length, 8¼ miles; lockage, 45 feet. Summit level, Lachine to Côte St. Paul, 5¾ miles long, mean width, 150 feet. Reaches, downward to Montreal, 3 miles; mean width, 200 feet; intended depth, 15 feet; 5 locks, each 270 feet long, 45 feet wide in the chamber—three of which have 14 feet depth of water on the sills, and two at the lower entrance, together with adjoining basins between Grand Trunk Railway at Point St. Charles and Harbor of Montreal, are adapted to vessels of 18 feet draught.

Five swing bridges on piers of cut stone, having an opening 46 feet wide on each side of centre for passage of vessels, and a waterway, 32 feet wide, on both sides of canal.

Lock walls throughout, also the basin and dock walls for one mile above lower terminus, are of cut stone laid in hydraulic cement mortar. Thence upwards for half-a-mile the dock walls are of random coursed masonry laid in cement mortar. Between the third and fourth locks, a distance of 1½ miles, the side walls are of random coursed stone laid at

right angles to a face inclination of two-thirds to one ; summit level, for 4½ miles, faced on both sides with masonry.

Entrance to Lake St. Louis formed of crib-work, on which is to be built a superstructure of masonry.

Dimensions of enlarged canals on St. Lawrence to be uniform from Montreal to Lake Erie.

Total cost of Canadian canals, when completed, will be about $55 000 000, of which about $33 000 000 is the cost of enlargement of St. Lawrence, Welland, and Ottawa Canals, $22 000 000 having been expended on canals previous to Confederation in 1867.

Dredging Ship Channel below Montreal.

After an abortive attempt by the Government to cut a new channel through the flats of Lake St. Peter, between the years 1844–1847, the work was undertaken in 1851 by the Harbor Commissioners of Montreal, Hon. John Young, Chairman, in the natural channel. In 1866, the depth of 20 feet was obtained where before was only 11 feet at low water. In 1875, dredging was resumed for draught of 25 feet depth at low water, which result will be attained next year. The present depth is for 22 feet draught of water.

The points of dredging extend over about one hundred miles of river, commencing 50 miles above Quebec, and form, in their aggregate length, over 30 miles of deepened channel, of which more than one-half is at one point—in Lake St. Peter. The dredging embraces all varieties from the silt of Lake St. Peter, through boulders and hard-pan up to shale rock at Cap La Roche. About 6¼ millions cubic yards have been dredged since 1874 out of the estimated 8 000 000 yards to be removed for the 25 feet channel. Last year 806 000 yards were removed from Lake St. Peter at a cost of $31 600, or an average of $3\frac{92}{100}$ cents per cubic yard—covering all charges except interest and depreciation. The minimum breadth of channel is 300 feet, in which there is now at low water a greater depth below the original bottom than above the same level; in other words, when completed, $\frac{14}{25}$ths of the depth of channel through Lake St. Peter will be artificial.

The effect of this work on the Port of Montreal is shown by the following figures :

Years.	Sea-going Vessels in Port.	Total Tonnage.	Value of Merchandise Exported.	Value of Merchandise Imported.	Customs Duties Collected.
1850	211	46 156	$1 744 772 00	$7 714 780 00	$1 009 256 80
1880	710	628 271	30 224 904 00	37 103 869 00	5 232 783 00

The number of vessels in 1880 included 354 steamships, their aggregate tonnage being ten times greater than that of all the vessels in 1850.

	1850.		1880.	
	Receipts.	Shipments.	Receipts.	Shipments.
Wheat, bushels	845 277	71 359	9 637 124	9 084 266
Indian Corn, bushels	51 965	5 719	7 772 549	7 622 161
Peas, "	21 256	98 006	2 617 656	3 081 674
Oats, "	3 677	1 061	1 191 531	1 853 829
Barley, "	512	350	357 176	293 023
Rye, "	.....	.....	443 528	452 847
Flour, barrels	483 603	182 988	735 596	739 007

There are no figures at hand to show the shipments (if any) of butter and cheese from Montreal in 1850. Some idea may be formed of the increase in the trade in these articles by comparing the following figures relating to the years 1870 and 1880 :

Shipments in 1870.		*Shipments in* 1880.	
Butter..7 763 976 lbs..value	$1 507 591	Butter..13 983 840 lbs..value	$2 882 360
Cheese. 5 633 883 " .. "	801 170	Cheese..34 776 180 " .. "	3 995 220

Canadian Railways.

There are over 7 000 miles of track laid, and another thousand under construction, besides over 2 000 miles of the Canadian Pacific Railway, under contract, on which construction has not yet been commenced.

The total Canadian mileage is only exceeded by that of the United States, Germany, Great Britain, Russia and France. In mileage, in proportion to population, Canada equals the United States, which in this respect surpasses every European country.

Of the $100 000 000 of Canadian capital invested in railways, over $99 000 000 are Government and municipal contributions, in the proportions of $74 000 000 by the Dominion Government, $27 000 000 by the Provincial Governments, and $8 000 000 by municipalities. Over $100 000 000 of share capital is held in England, and preference shares and bonds, in nearly equal proportions—chiefly held in England—supply the remainder, about $150 000 000, of the total cost.

Canadian Pacific Railway.

Length from Lake Nipissing to Burrard Inlet on Pacific coast, about 2 600 miles. From the Lake Nipissing terminus to Montreal, the dis-

tance is 340 miles. The section between Lake Superior and Red River, 406 miles, will be completed next year. 127 miles at Pacific coast, through the cañons of the Fraser, has been let for $9 000 000, and is to be completed in 1885. The whole line is to be completed in 1891. It will open a country which contains, between the Red River and the Rocky Mountains, over 250 000 000 acres of arable and grazing lands—more than half of which is arable.

The proportion of those undeveloped territories to that of the settled Provinces, is shown in the following :

AREA OF THE DOMINION OF CANADA.

PROVINCES.	SQUARE MILES.
Ontario	103 460
Quebec	193 355
New Brunswick	27 322
Nova Scotia	21 731
Prince Edward Island	2 133
Manitoba	153 250
British Columbia, including Vancouver and other Islands	390 344
North-West Territory	1 891 400
Keewatin District	309 077
Islands in the Arctic Ocean	311 700
Islands in the Hudson's Bay	23 400
	3 427 172

Statement reconstructed (to date) of areas of the several Territories, Provinces and Districts comprised in the Dominion of Canada.

J. S. DENNIS,
D. M. Int.

OTTAWA, June 7, 1881.
Certified, A. R.

On Thursday, June 16th, when the special train approached Ottawa, a Reception Committee welcomed the Society, and distributed a special programme for the day, which was also handsomely printed, bound in pocket form, and which read as follows:

PROGRAMME FOR THE RECEPTION OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS AT OTTAWA, JUNE 16, 1881.

PROGRAMME.

The visitors will arrive at the station of the Q. M. O. & O. R. R. at 1 o'clock P. M. Conveyances will take them *via* Queen and Bridge streets to near the Saw Mills at the Chaudière Falls. After inspecting the

Falls, Mills, etc., the party will drive across the Suspension Bridge, as far as the Sash Factory of Mr. E. B. Eddy, in Hull. Any of the party desirous of running the slides will be taken to near Mr. Rochester's Saw Mill, Queen street, where the cribs will be in readiness, and any of the visitors not desirous of descending the slides will be driven down Middle street, to near Messrs. Bronsons' Mills, where they can see the party descend the Slides. The entire party will thereafter assemble on Middle street, near Bronsons' Mills, and be driven to the Grand Union Hotel, where luncheon will be served at three o'clock, sharp. At four o'clock the party will visit the Parliament Buildings, Library and Grounds, and any desirous of visiting the residence of H. E. the Governor General, will be driven to Rideau Hall, on making application to the Secretary. The party will assemble at the Grand Union Hotel at 5:30, sharp, when they will be driven to inspect the Water Works, near Pooley's Bridge, and from thence to the Railway Station.

The following gentlemen, subscribers, have been constituted the Reception Committee, and will be glad to give all the assistance and information required to further the enjoyment of those now visiting the Capital of the Dominion: Allan Gilmour, Esq., Ottawa; Bronsons & Weston, lumber manufacturers; Perley & Pattee, lumber manufacturers; J. R. Booth, Esq., lumber merchant; John Rochester, Esq ,M. P., lumber merchant; Levi Young, Esq., lumber merchant; E. B. Eddy, Esq., lumber merchant; Gilmour & Co., lumber merchants; David Moore, Esq., lumber merchant; Thos. McKay & Co., flour merchants; Samuel Keefer, Esq., C. E.; T. Trudeau, Esq., C. E., Deputy Minister Railways and Canals; John Page, Esq., C. E., Chief Engineer Canals; G. F. Baillargé, Esq., C. E., Dep. Minister Public Works; F. N. Gise borne, Esq., Supt. of Telegraph and Signal Service; Col. Brunel, C. E., Commissioner of Inland Revenue; C. Blackwell, Esq., C. E., Dept. Railways and Canals; Sandford Fleming, Esq., C. E., C. M. G.; Thos. C. Keefer, Esq., C. E., C. M. G.; Walter Shanly, Esq., C. E.; Frank Shanly, Esq., C. E.; Thos. S. Scott, Esq., Chief Architect Public Works Dept.; H. F. Perley, Esq., Chief Engineer Public Works Dept.; Collingwood Schreiber, Esq., Chief Engineer Canadian Pacific; W. P. Anderson, Esq., Dept. Marine and Fisheries; Col. Dennis, Dep. Minister of Interior; W. B. Smellie, Esq., C. E., Canadian Pacific Railway; F. A. Wise, Esq., C. E., Supt. Rideau Canal; C. H. Mackintosh, Esq., Mayor of Ottawa; Lindsay Russell, Esq., Surveyor General; Leonard G. Bell, Esq., C. E.,; J. G. Macklin, Esq., C. E.; William Kingsford, Esq., C. E.; R. C. Douglass, Esq., C. E., Dept. Railways and Canals; J. Tomlinson, Esq., C. E., Dept. Railways and Canals; T. Ridout, Esq., C. E., Dept. Railways and Canals; G. P. Brophy, Esq., C. E., Ottawa River Works; Robert Surtees, Esq., City Engineer, Ottawa; James Goodwin, Esq., Ottawa; William Davis, Esq., Ottawa; Francis Clemow, Esq., Ottawa.

The following gentlemen, members of the Executive Committee, will attend personally to the requirements of the visitors: W. B. Smellie, C. E., Chairman of Committee; C. H. Mackintosh, Esq., Mayor of Ottawa; George P. Brophy, C. E.; F. A. Wise, C. E.; H. F. Perley, C. E.; J. G. Macklin, C. E.; and Robert Surtees, City Engineer, Secretary.

The following is a brief sketch of the principal points of attraction in the vicinity of the

City of Ottawa.

In 1854, the population of Bytown—now Ottawa—was 10 000, and from that time its progress has been uninterrupted. The great fire of 1870 was the means of maturing a scheme which has resulted in the present water works system.

Her Most Gracious Majesty Queen Victoria decided upon the present location for the Parliament Buildings, and they were commenced in December, 1859.

Among the improvements effected since Confederation at the expense of the city alone may be mentioned:

Five new Market Buildings, costing	$90 000
Dufferin Bridge and improvement to Sappers' Bridge	90 000
Pooley's Bridge at the Chaudière	18 000
Bridges across Rideau River and Canal	9 000
New Iron Bridge across Slide Channel	45 000
Main drainage	295 000
New City Hall	90 000
Registry Office	12 000
Water Works	1 014 000
Collegiate Institute	60 000
Central School Buildings	42 000
Fire Stations	5 000
Making an aggregate expenditure of	$1 770 000

in less than twelve years for city public improvements alone.

The population at present is over 26 000.

Rideau Canal.

This canal was commenced by Colonel By, R. E., in 1826, and consisted in utilizing two rapid and obstructed streams—the Rideau from Ottawa and the Cataraqui from Kingston into one continuous navigable channel. This object was accomplished by the construction of 47 locks, 24 dams, and 24 waste and regulating weirs. Of these locks 33 ascend from Ottawa and 14 descend towards Kingston, embracing a total lockage of 446¼ feet, of which proceeding southward there is a rise of 282¼ feet and 164 feet fall. The locks are constructed of cut stone masonry, their dimensions over all being 134 feet, or 110 feet clear by 33 feet in

breadth, with a navigable depth throughout of 5½ feet. The length of the canal from Ottawa to Kingston on Lake Ontaria, is 126¼ miles. The works were constructed by the Imperial Government, and originally cost about $4 000 000. This canal is now under the control of the Dominion Government, and Mr. F. A. Wise, Superintending Engineer.

The Parliament Buildings.

These buildings are generally known as the Eastern, Western and Central Blocks. The latter contains the Legislative Chambers and Parliamentary offices and Library—the two former the various departments of the Government. The three blocks form as many sides of a square, which is open to Wellington street on the south. The grounds, which were naturally very rough, have been laid out in walks and drives. A noteworthy adjunct to the grounds and surroundings is the "Lovers' Walk," a delightful winding path, which threads the edge of the precipice surrounding the grounds on the river side at an approximate distance of half way between its summit and the Ottawa river. The general style of architecture of the buildings is a modified twelfth century Gothic. The principal material used in the construction is a hard cream colored sandstone from the adjoining Township of Nepean. The dressings, stairs, gablets, pinnacles, &c., are of Ohio freestone, whilst a pleasing variety is given to the whole by the relieving arches of red Potsdam sandstone over the window and door openings. The roofs are covered with slate of a dark color, with bands of a brighter hue, obtained from the State of Vermont. The marble was obtained from Arnprior, and other localities in the Ottawa Valley, and all the timber used in the construction, except the oak, came from the Valley of the Ottawa.

The basement floors of the central building are 160 feet above the low water level of the Ottawa river, the Eastern and Western Blocks being respectively 135¼ and 142½ feet above same level. The central building has a frontage of 472 lin. feet, 3 stories in height. The central tower has an altitude of 220 feet, and a superficial area of 30 feet square.

The superficial area covered by the buildings is as follows: Central building, 82 886 sup. feet; Eastern Block, 41 840 sup. feet; Western Block, 50 176 sup. feet; or a total area of near 175 000 sup. feet, or 4 acres.

The Library is connected with the central building. The ground plan is of circular shape in the centre, inscribed by a polygon lean to of sixteen sides; at each of the sixteen angles are buttresses carried up solid to a point above the top of the lean to, serving as bases for the flying buttresses, which receive the thrust of the main vault. The general exterior view presents the form of a cone; the roof is groined, with ribs of stone filled in with solid masonry, and supported by marble

columns, resting on corbels of the same material. The groin is 42 feet in height, and the springing line 40 feet over the floor. In the centre of the vaulted space is an opening of 30 feet in diameter ; the main ribs being so arranged as to touch its circumference, and continue in a vertical plane between the springers ; above this opening is a groined lantern 42 feet high, the top of which is 124 feet above the floor level.

The total expenditure on these buildings and grounds is over five million dollars.

Rideau Hall.

The official residence of His Excellency the Governor General is situated in the Village of New Edinburgh, a suburb of Ottawa. It was built as a private residence by the late Hon. Thomas McKay, a man early identified with the chief interests of Bytown. About 87 acres of land are attached, and the amount expended for this property by the Dominion Government is over $300 000. The finest cricket ground in the Dominion is located on this domain.

Suspension Bridge (Chaudière).

On the Union of the Provinces in 1841 steps were taken to renew the inter-provincial communication, and in 1842 the present structure was commenced, the engineer being Mr. Samuel Keefer. The construction occupied over two years. The bridge is 256 feet span ; width of roadway 23 feet 6 inches.

The City Public Buildings

Include the City Hall, which is of the modern style of architecture, with a leaning to the French style, and constructed of massive dressed limestone blocks, with cut stone trimmings. It is centrally and conveniently situated on Elgin street ; at its northwest corner is a tower rising 175 feet above the pavement, used for the fire alarm offices ; the internal arrangements are most commodious and complete. It contains the offices of the several officials and a public council hall, committee rooms, etc., with all desirable modern appliances. The total cost was over $90 000.

The markets include the old and new By Ward Market, the Wellington Ward Market, and two subsidiary markets on Anglesea and Cathcart squares.

The City Registry Office, on Nicholas street, a substantial stone building on the general Government plan, cost $12 000.

The County Buildings comprise the Court House, Jail and Registry Office buildings. They are surrounded by a massive cut stone wall, surmounted by handsome wrought-iron cresting. They are of a very substantial character.

The Public School Buildings are of substantial character, and cost as follows:

	Land.	Building.
Victoria Ward (Primary)	$5 050	$10 000
Wellington Ward (Central)	6 780	24 000
" " (Primary)	5 460	4 500
St. George's Ward (Primary)	2 400	10 000
By Ward (Central)	2 100	10 000
" (Primary)	600	3 500
Ottawa Ward (Primary)	600	2 000

Or a total of nearly $90 000 expenditure on public school buildings within ten years.

Churches.—There are 24 Churches in Ottawa, as follows: 1 Baptist, 1 Congregational, 1 German Lutheran, 5 Episcopal, 5 Methodist, 5 Presbyterian, and 6 Roman Catholic. Most of these are very fine edifices, while some of them are exceptionally so, particularly the Cathedral, St. Patrick's, St. Andrew's, Christ's Church, Knox Church, the Baptist, and Dominion and Episcopal Methodist. Christ Church cost $45 000; Dominion Methodist, $50 000; St. Andrew's, $60 000; Knox's Church, $52 000; St. Patrick's, $40 000; Baptist, $30 000.

Sewerage.

The principal outfall sewer commences at the west end of the city. It is of egg shape pattern, 3 ft. 9 in. by 3 ft.; brick; runs easterly through earth and rock alternately for 1 119 yards, at which point it increases in size to 4 ft. 3 in. by 3 ft. 4 in. in a distance of 582 lin. yards, passing under the Rideau Canal to Rideau street, at which point it is again enlarged to 6 ft. 6 in. by 4 ft. 4 in. in brick and stone, passing through earth and rock excavation a distance of 2 411 yards, where it discharges into the Ottawa River near the Rideau Falls. The average depth is about 20 feet, the grades varying from ·15 to 1·5 per 100, except at the discharge, where the grade is 30 in 100 The Chaudière outfall sewer is egg shape pattern, 4 ft. by 2 ft. 8 in., 870 yards in length through solid rock; average depth, 16 feet. The main sewers commenced in 1874 and completed in 1877, at a cost of $395 000.

Streets.

On the east side of Canal the total length of streets is 31 miles, of which 8¼ miles are either paved or macadamized. On the west side of the Canal there are 30 miles of streets, of which 24 miles are improved, and 7½ miles paved or macadamized.

Water Works.

The supply is a water power-pumping one, under the "direct" system, without stand-pipe or reservoir. It differs from the Holly

system of the United States in that the same machinery is employed for fire as well as for ordinary purposes; the greater delivery required for fires being effected by an increase of speed, or of the number of pumps, or of both, without the necessity of exceeding the ordinary working speed of reciprocal pumps. The works will be best described from the source of supply to the points of delivery under the following heads of—

1st. The Source of Supply.

The water is obtained from the Ottawa River, above the Chaudière Falls, at a point where there is a strong current flowing over a rocky bed. The river for more than one hundred miles above the city is a succession of large deep lakes, forming magnificent natural reservoirs, from which the water is decanted over rocky chutes until it reaches the city in the condition of lake water aerated by the rapids above. The difference between Ottawa and St. Lawrence water as to purity, apart from color, may be inferred from the fact that a single drop of coloring matter will tinge a quantity of water in which a teaspoonful of salt may be dissolved without detection by the eye.

2d. The Water Power.

The Falls of the Chaudière range from 25 feet at high to 35 feet at low water, the difference being due to the fact of a rise of two feet below to one foot above the Falls during freshets. The wide expanse of Deschênes Lake, into which no tributaries of importance are discharged, prevents a rapid rise above Ottawa, while below, the comparatively narrow and shallow reach between Ottawa and Greenville, receives some half dozen important tributaries, sending up the flood level of this portion of the river fully 20 feet above low water mark.

3d. The Aqueduct.

A canal 2 500 feet in length has been cut through the solid rock, 20 feet wide, with perpendicular sides, to a depth of about 13 feet below low water of the head level. The entrance is formed by two lines of crib work, each 20 feet wide and about 200 feet long, placed 60 feet apart, boomed across at the head, and provided with stop logs, and divided by a central pier containing a well, fitted with screens, from which the pure water supply-pipe for the pump is fed.

4th. Pure Water Pipe.

A trench about three feet in width and one foot in depth is excavated in the bottom of the aqueduct, in the bottom of which trench, at intervals of twelve feet, iron bolts are imbedded in the rock, for the purpose of anchoring the clean water from the river, because the aqueduct at present receives such local drainage as may penetrate through the rock in banks above it.

The clean water pipe is 30 inches diameter inside, and is formed of pine staves 2 inches thick, hooped every 4 feet with 3 in. by $\frac{3}{8}$ in. iron, (except for the anchorage, where the iron for the hoops is 3 inches by $\frac{5}{8}$ inches thick), open at the bottom, and secured with $\frac{3}{4}$ inch bolts through the eyes of the anchors. The anchor bolts are 1 inch diameter, with strong head, containing the eye, sharpened at the points, let 18 inches into the rock, and secured by first dropping a soft pine tree nail, about $\frac{1}{4}$ of an inch less in diameter than the drill hole, into the latter, and then driving the eye-bolt through the wood to its position. Each bolt was subjected to a lifting strain of $2\frac{1}{2}$ tons after being driven, but none could be removed. The strain was increased in one case to test the resistance, but the bolt broke without drawing. The lower end of this pipe leaves the bottom of the aqueduct about 70 feet above the forebays, passes under the retaining walls, and goes to the pipe vault in rear of the pumps, this section, about 100 feet in length, is cast-iron, and the portion within the wheel-house is provided with valves between each set of pumps, and is connected (below the pumps) with a 24 inch pipe leading from the aqueduct in front of the wheel-house. The pumps must have water, and if from any cause the supply from the clean water pipe should be interrupted, aqueduct water can be drawn upon.

5TH. PUMPING MACHINERY.

This consists of three distinct sets, each capable of delivering over 3 000 000 gallons in 24 hours, under a pressure of 150 lbs. at the pumps. Each set is capable of affording a supply for domestic purposes to double the population now receiving it. This large provision of pumping power is necessary in the absence of a high level storage and distributing reservoir, as well as for the requirements of a large fire, to which Ottawa, by reason of its extensive lumber yards and many wooden buildings, is peculiarly exposed. The demands of a great fire being measured by the delivery of a given quantity in a given time under the required pressure, can be more readily and safely met by large pumps moving slowly than by smaller ones at a higher velocity, as in the "Holly" system. Two sets are sufficient for any emergency; and with three sets, two can always be ready for the fire alarm while the remaining one is being overhauled. The wheel-house is the reservoir of the Ottawa Water Works, and it is therefore of the first importance that it should be capable of meeting any and every demand upon it; with water power this can be done in the most perfect manner, for, unlike steam, here all the required power is held in reserve without extra cost. The wheels are Leffell's double turbine, 61 inches in diameter, seated at the level of the bottom of the aqueduct, having their discharges about 12 feet below low water level of forebays, and more than 20 feet below water level of the Ottawa river below the Chaudière Falls.

The "steps" are, therefore, always accessible during the highest known floods. To utilize the whole fall at all times, wrought-iron draft tubes, 5½ feet diameter, air tight, extend from the bottom of the wheels to a depth of 14 feet, giving a total available head and fall at low water of 25 feet, with a clearance of 5 feet depth in tail race below the bottom of the draft tubes. The wheels are worked by water pressure from the mains, acting on a piston connected by each, and pinion with the gate spindle controlled by a small globe or "thumb" valve. Pumps—The pumps are in sets of three, driven by one water wheel, and are cast-iron chests, having a suction chamber below and a delivery one above the pump barrels. The valves connecting each chamber consist of two rows, four in each, of rubber discs 9 inches in diameter, and 1⅜ inches thick, working on a centre spindle, with brass seats and springs. The plungers are 19 inches diameter, with a stroke of 3 feet 6 inches, cast hollow, to "float" as much as possible, and thus reduce the weight on their horizontal bearings. The pump chests are connected with the pedestals of the crank-shaft by strong distance girders, bearing against horizontal thrust upon the foundations. Each set of machinery, making 17 revolutions of crank-shaft per minute, will pump, allowing for loss, a little over 3 000 000 imperial gallons per 24 hours, so that the diurnal capacity of each pump at safe limits of speed may be called 1 000 000 of imperial gallons. Each set is sufficient for the domestic wants of 50 000 people, so that without further outlay here or increased cost of working expenses, a population of 100 000 can be served with one complete set in reserve. The whole machinery occupies a floor space of about 48 feet square, covered by a fire-proof ceiling of iron girders, supporting "Dennet" arches of brick overlaid with sand.

A fire-alarm gong is placed in the machinery room. When an alarm is struck, the pressure, which is ordinarily about 85 lbs. at the pumps, is at once raised to 110 lbs.

Height of Fountain Jet at Pump House, from trignometrical measurement:

2¾ nozzle,	90 lbs.	pressure	192	lin. feet.
"	100 "	"	209	"
"	120 "	"	242	"

The cost of the whole system was as follows:

Water power, including wheel-house and foundations, aqueduct, and all structures connected therewith	$215 000
Pumping machinery, 3 sets	90 000
Distribution, 43 miles, including culverts	490 000
Fire-alarm	7 000
Engineering	40 000
Financial, land and general charges	172 000
	$1 014 000

The works were constructed under a Board of Water Commissioners, with Mr. Thomas C. Keefer, Chief Engineer, but they have for the past two years been under the management of the Corporation of the City of Ottawa and their officers.

River Ottawa.

The remotest sources of the Ottawa lie to the southeast of Hudson's Bay, near the 49th parallel of N. latitude. The upper portion descends from the northeast towards the southwest towards Lake Temiscamingue, a distance of about 300 miles; then suddenly turning towards the southeast, and following this general direction for about 400 miles, it discharges into the St. Lawrence at the head and foot of the island of Montreal.

Its total length is about 700 miles from its principal outlet to the village of Ste. Anne, or head of the island, and it drains an area of about 57 800 square miles. Its most important tributaries are the Rivière du Nord, Rivière Rouge, North Petite Nation, South Petite Nation, Rivière du Lièvre, Gatineau, Rideau, Madawaska, Bonnechère, Coulonge, Black River, Petewawa, Rivière du Moine, Mattawan and the Montreal river, and of these the largest is the Gatineau, which falls into the Ottawa from the north about 1½ miles below this city, after a course of about 400 miles, and having drained about 9 000 square miles of territory.

The Ottawa Valley

was for a considerable distance explored by the early French voyageurs, and passed through by the Hudson Bay and Northwest fur traders at a very early date, but little or nothing was done to promote its settlement or open it up to the ways of civilization until the latter end of the 18th, or the present century, when a colony was planted at Hull, on the opposite side of the river, about the year 1800; and these early settlers may be said to have been the pioneer farmers, lumberers, manufacturers, and merchants of this thriving district surrounding the capital of the Dominion.

The Lumber Trade.

The principal manufacturing industry in connection with the Ottawa Valley belongs to the production of square timber and sawed lumber, principally in white pine.

As many as 160 rafts of square timber have, in prosperous times, been taken annually from the Upper Ottawa limits or timber berths, and upwards of a million and a half of sawlogs. A raft of square timber may be said to contain on an average 80 subdivisions or cribs, equal to about 100 000 cubic feet in the aggregate. A crib of timber is about 25 feet in width by the length of the sticks, ranging from 35 to 80 feet, and the total output ranges from 12 000 000 to 16 000 000 cubic feet annually for this district. To facilitate the descent of timber on

the Ottawa, the Government first constructed slides at the various falls on the river about forty years ago, and the cribs are passed through them to escape the chutes. The principal slides on the Ottawa are at this city, at the Chats, 36 miles above this place, and at the Calumet Station, 65 miles from Ottawa.

The fall at the Chaudière (this city) is upwards of 30 feet, which is overcome by the slides in less than half a mile.

On the main tributaries the timber and sawlogs are passed through what are known as single stick slides to escape the chutes. These slides are about 5 ft. to 6 ft. wide by 3 ft. or 4 ft. deep, and in some instances are upwards of half a mile in length. At some of these structures, such as the Coulonge and Black River, the pieces of timber and logs are shot through with great velocity. Timber is guided through the safe channels, and kept under the control of the raftsmen in dangerous rapids by systems of piers and booms.

Square timber is exported from Quebec chiefly to the British and other European markets.

At the City of Ottawa, City of Hull and immediate vicinity, about 1 000 000 of sawlogs are cut up annually, producing about 200 000 000 feet B. M. of sawed lumber, the great bulk of which finds its way to the United States markets, the remainder being sent to Europe in the shape of deals, or absorbed by builders and others for home use. Sawed lumber on its way to market from this neighborhood takes the water route principally, although of late years the quantities transported over the various systems of railway tapping the Ottawa Valley have been very considerable, and likely to be largely increased with additional improved outlets.

About 29 years ago the Canadian Government leased the first installment of the Chaudière water privilege, and since then sold all the hydraulic lots, about 25 in number. With each lot power equivalent to the driving of 10 runs of stones is guaranteed, so that about 3 000 horse power may be said, through the agency of the Chaudière Falls, to be developed within the city limits. The lumber manufacturing establishments at this point are stocked with the most improved modern machinery, and, taken in connection with mills of a similar nature, and the very extensive match and pail factories at the City of Hull, on the opposite side of the river, form a source of attraction to scientific men and practical mechanics from various quarters of the globe. The various works for facilitating the moving of lumber on the Ottawa and its tributaries are under the control of the Minister of Public Works for the Dominion of Canada.

Minerals.

The Ottawa Valley is also rich in mineral productions. Within a short distance of this city there are immense beds of iron ore and

deposits of apatite or phosphate and plumbago in abundance. These, so far as they have been worked, have proved to be most excellent in quality, and only await the action of capitalists for development on a large scale, the more especially as the system of railways already constructed, and those now in progress and projected, cannot fail to give to the City of Ottawa and its environs a commanding position as a distributing centre.

On Saturday, previous to the session of the Convention, an exhibit was made of the high water service of the City of Montreal and of the working of its fire brigade. On the same day, after the adjournment of the Convention, the La Crosse grounds were visited and a game between the two prominent clubs was witnessed.

On Saturday evening a large number of the party proceeded, via the Grand Trunk Railway, to Quebec, staying at that city until Monday evening.

Another party on Monday went by steamer to Quebec by invitation of the Harbor Commission of Montreal through John Kennedy, Esq., member A. S. C. E., the Chief Engineer of the Commission. During this trip down the St. Lawrence the interesting work of deepening the channel by dredging was witnessed at a number of points.

In conclusion, it should be stated that the reception given to the Society in Canada was extremely cordial, and that remarkably complete arrangements had been made for the meetings at McGill University, for travel on the railways (largely provided by the courtesy of the Grand Trunk Railway, the Quebec, Montreal, Ottawa & Occidental Railway, and the Pullman Palace Car Company), for comfort at the hotels and for visits by carriage and steamer to various points. The Committees at Montreal and at Ottawa perfected and successfully carried out these arrangements, and the fact that the Canadian members of the Society were greatly aided in their work by a number of gentlemen who were not members renders this acknowledgement peculiarly appropriate.

The following members were in attendance at the Convention: —James H. Armington, Brooklyn, N. Y.; George D. Ansley, Montreal, Canada; E. W. Bowditch, Fred'k Brooks, Boston; William S. Barbour, Cambridgeport, Mass.; Henry A. Bently, Newport, R. I.; John W. Bacon, Danbury, Conn.; John Bogart, Alfred P. Boller, D. Bontecou, Henry R. Bradbury, New York; L. L. Buck, Brooklyn, N. Y.; A. Bonzano, Phœnixville, Pa.; R. J. Brough, Toronto, Canada; Wilson Crosby, Bangor, Me.; E. L. Corthell, North Egremont, Mass.; Francis Collingwood, J. James R Croes, New York; C. Constable, Constableville, N. Y.; C. L. Crandall, Ithaca, N. Y.; Martin Coryell, Lambertville, N. J.; Amory Coffin, Phœnixville, Pa.; E. S. Chesbrough, Chicago;

E. C. Davis, Northampton, Mass.; A. J. Du Bois, New Haven, Conn.; Joseph P. Davis, New York; E. A. Doane, Oswego, N. Y.; Alex. Dempster, Pittsburgh; S. Clarence Ellis, Boston; Charles D. Elliot, Somerville, Mass.; Theo. G. Ellis, Hartford, Conn.; Thomas Egleston, New York; George D. Emerson, Rolla, Mo.; Robert Fletcher, Hanover, N. H.; James B. Francis, Lowell, Mass.; Charles A. Ferry, Charles E. Fowler, New Haven, Conn.; Charles H. Fisher, Albany, N. Y.; Sanford Fleming, Ottawa, Canada; Bryant Godwin, New York; C. S. Gzowski, Toronto, Canada; Albert B. Hill, New Haven, Conn.; Stephen S. Haight, Bentley D. Hasell, Sullivan Haslett, New York; Wm. P. Harris, Newark, N. J.; E. P. Hannaford, Montreal, Canada; R. Hering, Philadelphia; J. E. Hilgard, Washington, D. C.; George A. Kimball, Somerville, Mass; Louis H. Knapp, Buffalo; John Kennedy, Montreal, Thomas C. Keefer, Ottawa; Samuel Keefer, Brockville, Canada; E. D. Leavitt, Jr., Cambridgeport, Mass.; Charles Latimer, Cleveland; Thomas D. Lovett, Cincinnati; Wm. H. Lotz, Chicago; Sidney F. Lewis, New Orleans; Henry Manley, Boston; C. C. Martin, Brooklyn, N. Y.; Henry G. Morris, Philadelphia; Mansfield Merriman, Bethlehem, Pa.; C. S. Maurice, Athens, Pa.; A. G. Menocal, Washington, D. C.; Robert E. McMath, E. D. Meier, St. Louis; John MacLeod, Louisville; George H. Norman, Boston; S. C. Pierson, Meriden, Conn.; Henry G. Prout, New York; P. A. Peterson, Montreal, Canada; Joseph R. Richards, Boston; Robert L. Read, Cincinnati; D. McN. Stauffer, Boston; T. Guilford Smith, Buffalo; F. Slataper, C. L. Strobel, Pittsburgh; George H. Simpson, Terre Haute, Ind.; W. G. M. Thompson, Welland, Canada; John G. Van Horne, Jersey City, N. J.; Frank O. Whitney, Henry M. Wightman, Boston; Wm. H. Wiley, Wm. E. Worthen, New York; Charles D. Ward, Lebbeus B. Ward, Jersey City, N. J.; Ashbel Welch, Lambertville, N. J.; H. F. Walling, Washington, D. C.; Fred. C. Weir, Cincinnati; A. F. Wrotnowski, New Orleans.

MEETINGS OF THE SOCIETY.

June 1st, 1881.—The Society met at 8 p. m. Vice-President Welch in the chair.

Ballots were canvassed and the following candidates declared elected:

As Members, Jacob Blickensderfer, of Omaha, Neb.; Robert Blickensderfer, of Terminus, Montana; Cabell Breckenridge, of Chattanooga, Tenn.; Stephen S. Haight, of West Farms, N. Y.; William P. Harris, of Newark, N. J.—as Junior, Hunter Stewart, of St. Louis, Mo.

The following amendment to the Constitution was presented and read: Any member or associate whose subscription is not in arrears may compound for future annual subscriptions by the payment of three hundred dollars, if he is a resident, and of one hundred and fifty dollars,

if he is a non-resident. But should a non-resident become a resident he shall pay the remainder of the composition, viz.: one hundred and fifty dollars, or the usual annual subscription during the time of his residence.

This amendment was signed by the following named members: G. Bouscaren, William E. Merrill, Robert L. Read, F. de Funiak, C. Shaler Smith.

The paper by C. L. McAlpine, read May 18th, 1881, was discussed by Messrs. Chesbrough, Wm. Sooy Smith, Welch, Macdonald, Joseph P. Davis, Striedinger and (by letter) William R. Hutton.

June 17th, 1881.—Business meeting at Thirteenth Annual Convention. The President, James B. Francis, in the chair.

The following report of the Committee on a Uniform Method for Tests of Cements was read by the Secretary:

To the American Society of Civil Engineers.

John Bogart, *Secretary:*

The undersigned, Chairman of the Committee appointed to devise and report a uniform method of cement tests to your Society, desires to make the following report of progress:

The Committee have had under advisement during the past year the matter of forms of test specimens, and of what kinds of tests should be employed, and such matters as are closely connected therewith. It is found the European practice generally embraces tests of mortars composed of certain definite mixtures, by weight, of cement and sand; that is to say, one weight unit of cement with one, two, three or four units weight of sand. No one can question the advisability of testing mortars containing the sand mixture, as in practice the bulk of our mortars is largely composed of sand. It has been the desire of the Committee to so perform their duty that whatever system they might recommend would be one from which the results of different experimenters could be compared in arriving at a correct opinion of quality, and that the system might be one that in a few years the Society would not be compelled to change. Knowing that our American hydraulic cements vary in weight of equal bulks 20 per cent. and over, and that almost similar variation exists in the weight of equal bulks of sand, it is readily seen that the European practice of using equal units of weight, regardless of bulk, in making mortar mixtures, would *per se* be so indefinite as to preclude comparability of tests. The variability of sand in weight, in fineness and in sharpness caused me to hesitate, in pressing before the other members of the Committee, the advisability of making our final report until I had an opportunity to make, at least, a partial examination of the physical qualities of our American sands, and to this end, at about the termination of last year, I had devised a scheme for making a collection

of sands from different sections of our continent, and, when received, intended to carefully examine same as to sharpness, fineness, voids and weight of equal bulks, &c., so as to proceed understandingly with the duty allotted to us, and, if possible, engraft in the system of tests only such safeguards as were found absolutely necessary, as it is the undoubted desire of not only the members of the Society, but of your Committee also, that any system of tests should be made as simple as possible consistent with the end desired—uniformity. When ready to commence this inquiry, severe domestic affliction visited my household which precluded my devoting evenings to this study. For many years previously the greater share of my evenings have been devoted to the subject of cements, and my other duties are such that I have no other time to spare for this subject. The affliction to which I alluded still continues, and may continue for months, and until this ends I can give the subject very little thought; but when it does end I hope and intend, whether continued as a member of said Committee or not, to pursue the inquiry, and report the results to your Society. At present I can only say that my knowledge of the subject is so deficient in this and some other particulars that I do not feel it advisable or safe to ask your Committee to formulate a system of cement tests such as will be demanded and will suit our American products and practice.

With more knowledge and under favorable circumstances, which I trust to secure during the present year, I hope to feel competent to aid any Committee you may continue or appoint for the purpose in defining a proper mode of conducting tests of cements.

Respectfully submitted,

D. J. Whittemore,

Chairman.

Milwaukee, June 6, 1881.

On motion, the report was received, and the Committee continued.

The Secretary read a supplementary request on the same subject, as follows:

The Committee appointed by the American Society of Civil Engineers to devise a uniform method of cement tests, desire to procure from several localities throughout the United States and Canadas specimens of sands ordinarily used in the fabrication of cement mortars for the purpose of investigating their properties as to fineness, weight, voids, etc., with a view of recommending a practicable standard to be used in mortar mixtures of sand and cement for test purposes.

Will you kindly select and send the subscriber by express from your locality, say, two specimens, one of sharp bank sand, if you have any ordinarily used, also one specimen of shore washed or water worn sand, and mark plainly on each package your name and from what locality the sand is taken.

Please do not send much less or any more than about one pint of each kind of sand.

Yours very truly,

D. J. WHITTEMORE,
Chairman of said Committee.

The Secretary said that the Committee on the Preservation of Timber simply asked to report progress, stating that they were collecting a great many samples of timber from various parts of the country, and were endeavoring to put their investigations into form.

On motion, the report of progress was received, and the Committee continued.

The Secretary read the following report of the Committee on Tests of Iron and Steel:

To the President of the American Society of Civil Engineers:

SIR,—The Committee of the American Society of Civil Engineers on Tests of Iron and Steel, beg leave to submit the following report:

As the members of the Society must be aware, the United States Board appointed to test American iron and steel was legislated out of existence just as its labors, which promised to be invaluable, had fairly commenced. By far the best testing machine in the world had been constructed and erected under the direction of this board, and with funds appropriated for the purpose by the Congress of the United States, at the urgent solicitation of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Iron and Steel Association, and other scientific societies and institutions.

The scientific and technological schools and colleges of the whole country joined earnestly in recommending and urging these appropriations. These solicitations and recommendations clearly indicate the general interest felt throughout the country in this effort to obtain, for the use of all, such accurate knowledge of the qualities of the iron and steel used in the United States as would guide to their safe employment for all the purposes to which they are applied in the trades, arts and industries of the country.

The legislation obtained and the organization of the board and the investigations and experiments planned by it were broad and comprehensive, and the labors of the board were auspiciously begun. Meantime repeated efforts had been made to subject the board to the control of the Ordnance Department of the United States army. This, in the opinion of your Committee, would have resulted in injurious limitations on the labors of the board, and it would have been unjust to the engineer officer of the United States Army, to the two officers of the United States Navy, and to the three civil engineers who were members of the board.

On the other hand, no good could result from such control, and no reason could be discovered for the efforts made to obtain it, other than the desire of the Ordnance Department to secure to itself the credit of the investigations to be made by the board.

These facts have been presented to the Society in previous statements made to it by your Committee, but they have thus far failed to arouse the Society to such action as would have prevented the hostile legislation in the first instance, and which will yet, if vigorously taken, secure the passage of a new bill repealing it, rehabilitating the board, and restoring the testing machine to the uses for which it was intended and built.

Your Committee would therefore recommend that a memorial and petition to Congress be prepared and signed by the officers of the American Society of Civil Engineers, setting forth the history of the effort made to secure a complete set of tests of iron, steel and other materials used in construction in this country, and praying that the board legislated out of existence shall be reappointed, the testing machine built under its direction restored to its possession, and that additional appropriations be made to enable the board to complete its labors.

If this recommendation is approved and carried into effect, your Committee also recommend that every member of the American Society of Civil Engineers shall take an active personal interest in obtaining the favorable action of Congress upon the petition proposed, and that the Society, as such, shall ask the active co-operation in this effort of all the scientific societies and colleges, and of the associations of tradesmen, mechanics, engineers and manufacturers in our country.

In response to a request sent to Colonel T. T. S. Laidley, U. S. Ordnance, President of the late U. S. Testing Board, he has kindly furnished your Committee with the following report of the duty performed by the testing machine :

WATERTOWN ARSENAL, June 11, 1881.

Gen. W. S. SMITH, No. 31 East 22d street, New York :

DEAR SIR,—In reply to your inquiry of this date, I have to say, that since the 1st of July last, when the funds became available, the testing machine has been constantly at work, about one-half of the time for private individuals, the Pennsylvania Railroad Co., the New York and Brooklyn Bridge, Passaic Rolling Mill Co., Mr. Andrew Kloman, and Mr. E. D. Leavitt, Jr., being those who have had most work done. 734 specimens have in all been tested.

The first work was to test the cylinders of cast iron prepared under authority of the board for testing iron and steel. The results in brief are given in the annexed table, and establish the important fact that

cast iron, such as is used in making guns, makes a stronger gun than a similar one made of cast and lined by a wrought iron tube.

Experiments have been made on the resistances of woods, and provision made to extend them much, as soon as the wood shall have become sufficiently seasoned.

Arrangements have been made to test a large number of iron columns, and this will commence in a day or two.

Trials have been made on the transverse strength of pins of various sizes and lengths, and on sliding and rolling friction.

Experiments have been made to determine the effect of rerolling iron for bridge work. Quite a number of tests of eye bars have been made to determine the best method of forming the eyes, the strength of riveted work for boilers, and bridges, wire rope and fastenings, open hearth steel, stone, etc., etc. The experiments made for individuals will not be published ; those made on Government account will accompany the report of the Chief of Ordnance.

It is much to be regretted that the law was passed requiring the use of the machine to be given to any one who will pay the actual expenses, for, as the law now stands, such persons have the precedence.

Respectfully yours,

T. T. S. Laidley,

Colonel of Ordnance, Commanding.

CYLINDER TESTS.

Distinguishing Mark.	Under Initial Load of 5 000 lbs. on Piston.			Ultimate Loads.	
	Length of Bore filled with Wax.	Surface of Bore exposed to Wax.	Volume of Wax, cubic inches.	Actual lbs.	Lbs. Sq Inch Internal Pressure.
	Inches.	Sq. Inches.			
A 1	10.064	113.00	86.23	769.200	83.518
A 2	10.371	116.37	89.13	737.600	85.867
A 3	10.445	117.03	89.62	792.500	92.366
B 1	10.097	112.71	85.62	635.500	74.936
B 2	10.010	118.81	84.88	687.900	81.120
B 3	10.471	116.57	88.79	660.200	77.853
C 1	10.388	115.71	88.09	735.400	86.722
C 2	10.385	115.61	87.96	698.100	82.420

A Lined with thin copper $\frac{1}{10}$ inch thick.

B Lined with wrought iron 0.912 inch thick.

C Lined with bronze 0.508 inch thick.

Cylinders 22 inches long, 11 inches diameter. Diameter of bore, 3.3 inches.

A 1 and A 2 were bored through, and the breach end closed with a screw.

T. T. S. LAIDLEY,
Colonel of Ordnance.

Respectfully submitted,
WM. SOOY SMITH,
Chn. Com. on Tests of Iron and Steel.

A. P. BOLLER.—This commission was commenced as long ago as 1873 or '74. I was familiar with its constitution at the time, and did what share of work I could to get it launched and into practical working order. Since that time we have been much disappointed in the results obtained by that commission, and from the admissions of their own report there is evidently such a clashing of authority that we cannot expect the work to advance in the direction or to the extent that we all hoped for. I would move, therefore, in order to examine the true condition of affairs, and without any disrespect to the gentlemen composing the commission, that the report be referred to the Board of Direction for examination as to its inferences and charges, and that the committee be discharged and thanked for the work they have done up to the present time. The result of such action will be, I think, getting at the real facts of the case, and a reorganization as it were, of the part our Society has taken and must take in furthering this work ; for there is no scheme that has been started for the advancement of American engineering, in my judgment, comparable with the work that was laid out for the investigation of that commission. It is so far beyond the possibility of private effort that we must have hearty Government co-operation in it. No steps should be taken unadvisedly or hastily, and it is for that reason I move that the report be referred to the Board of Direction for examination, or to a special committee—I do not care which—for examination into the charges and jealousies therein contained, to report to the Society for future action, and that the committee be discharged with thanks for past labors. But as it would be better to divide my motion into two parts, I would move first for the acceptance of the report, and the discharge of the committee with thanks.

Motion agreed to.

A. P. BOLLER.—I now move that a special committee be appointed to whom that report shall be referred for report at the earliest practicable moment, with recommendations as to the future action of the Society in the matter.

F. COLLINGWOOD.—To whom does that report come ?

A. P. BOLLER.—It was to be a committee to examine into the working of the commission, and into the charges conveyed in their report. We are

plainly told that the differences and jealousies between the civil and military departments have utterly blocked the useful working of the commission, and we will stand where we are to all eternity if we do not have that obstacle removed out of our way.

The President.—I question whether that is a proper mode of proceeding, whether it would be altogether in order to appoint a committee to report upon the action of another committee just discharged. Of course, it is just as gentlemen choose to vote.

T. Egleston.—It is necessary that the bottom facts of this case should be known, but it is not necessary that the conduct of the committee should be scrutinized. It is possible, however, that somebody in authority should know exactly what the reasons are why this commission has failed of its object. In view of the greatest engineering problem that has been started in 200 years, and with the prospect of our doing for the metals what has never been done or even thought of before, it does seem to be about time this commission was organized and at work. Here is a commission with a large amount of money, with the patronage of the Government and the sympathy of its officers, with the machine already in hand, and yet it has not succeeded. I think it is desirable that somebody should know the reason why; it is not, I think, desirable that if there is any personal jealousy, or if there is anything approaching to a scandal, it should be made known to the public. The Governing Board of this Society is quite competent to discuss any question that may come up, and it therefore seems to me that if a committee is appointed to look over this matter and see what shall be done in the future, it should report to the Governing Board of this Society, and the advice of that Board should be taken. This investigation is of great interest, not only to engineers, but to all mankind, because it involves the whole question of factors of safety, and if there is to be any reorganization, the action preliminary thereto should come from the governing body of this Society.

The President.—I do not question at all the propriety of the investigation, but simply the form of proceeding to arrive at it. The question is whether it should be done by a new committee, with full powers to pursue the matter.

A. P. Boller.—It is apparently a little difficult to get at. We are not prepared now to appoint a new committee to prosecute this subject. A committee of that character must be selected with a great deal of forethought, and a great deal of examination into the qualifications of the members, and the time they can give to the matter. The obstacles which that report tells us exist, must be examined into in some form or shape, and I can conceive of no other way of doing it than to refer that report to a committee, or to the Board of Direction—I do not care which—for examination and deliberation as to the further action this Society should take in furtherance of the object of this great commis-

sion, for no greater one in the interests of science has ever been started. I am willing to accept any amendment that will get over questions of test or competency, for I am deeply convinced we must do something before we separate this morning for carrying forward the object of that commission.

The President.—My objection was to the appointment of a committee to criticise the action of a committee whose report we had just accepted. I question whether that would be in order, or is a proper thing for the Society to do. I think, however, it would be in order to refer it to the Board of Direction, with full power to pursue the matter.

A. P. Boller.—I am perfectly willing that the Board of Direction should take it up, and possibly we might profitably discuss the matter a little more before we pass a final resolution upon it. But as I have stated my views on the matter, and how I stand, I will withhold pressing my motion until we have heard further from the members of the Society.

F. Collingwood.—I think we can get over this difficulty by changing the words of the motion. It is in the minds of members about me, that a committee should be appointed, but there is an objection to the motion taking the form of criticism. I think it is not desirable that we should ask the Board of Direction to undertake the matter because they have already a great deal of work to attend to. The committee should be composed of men who have more leisure, and I would, therefore, suggest that the motion be put into this form : That a committee be appointed to examine further into the subject, and to report a recommendation to the Board of Direction, who shall take such action as they see fit. I think that will meet the whole matter.

Mr. Boller.—I accept that as an amendment.

C. Latimer.—It seems to me the appointment of another committee to continue the same subject is a criticism upon the former committee that has been discharged.

I am not acquainted with the merits of the question ; but it seems to me that I would not like to see another committee appointed to throw discredit upon a committee that has already done something and to throw discredit on their work. I think it would be better to refer the matter to the Board of Management to decide on the merits of the work, and that the committee should do what may be further necessary in order to carry out what the Board may recommend.

The President.—I should say it was perfectly in order to criticise the report of that committee before it was accepted, but after it has been received, I do not think it is in order to criticise what they have done.

A. P. Boller.—May I ask if a new committee is appointed to be active commissioners in the matter, whether the reports and past observations on this matter are not open to examination and criticism ? Whether the reports of the Board or the reports of a special committee on any other subject may not be examined, and whether it is not perfectly

competent for us to review the whole question, and see where the difficulty lies, and if there is difficulty, to remove it before there is trouble ? It is impossible to couch the motion in such terms as to preclude all criticism. I do not propose to critcise that committee. They are all gentlemen whom I esteem very highly, and I believe they have worked to the best of their ability in the matter. But they have evidently come to a standstill, and now we must find out just where that difficulty lies. When a matter of great importance is up, I do not believe in mincing matters. I believe in going to the root of the difficulty, and when that is found to eradicate it.

The President.—It is perfectly in order to refer the same subject to a new committee

A. P. Boller.—Very well, that is the point Mr. Collingwood made, and I accepted that as an amendment to my motion.

J. J. R. Croes.—There is a certain mystery in all this that we who are uninitiated cannot understand. We have a report presented which asks that this Society do something. We receive that report and discharge the committee. Then we ask for a committee to be appointed or for the Board of Direction to do something, but nobody seems to have a clear idea of what they do want, or of what the matter is. Why do not gentlemen who have these grievances behind them state whether they are against the Committee of the American Society of Engineers, or the National Board, or the Ordnance Board, or Congress, or whoever it may be. If they would state who it is they want to hit so that we can find out who they are, we will be much better satisfied, and it could be done in five words then.

A. P. Boller.—I do not know whether my friend, Mr. Croes, took a nap during the reading of that report, but I think the report itself is abundant cause for the discussion we have had on this subject. I have no grievance against Congress, or against the Engineers, or against the Ordnance, or against the Society, or against anyone else. I simply know that by their own admission their work has come to a standstill. They make certain charges in the report which, divested of all rhetoric and of all complimentary terms, reveals a clashing between the components parts of the Board, the one civil and the other military. Now there may be two sides to this question, as there generally are to all questions, and I am very anxious to get at the secret and see exactly what the trouble is. Unless we do that our past work is good as far as it has gone, but it is so far short of what we have been striving for that it is a confession of failure to stop at this point.

C. Latimer.—I would like to know what the members of the committee themselves think of the matter. It seems to me that if there is anything kept back, any trouble in the Commission, they ought to know all about it, certainly, and if they would only explain it to us now, we would be much obliged to them. It seems to me a curious proceed-

ing to appoint another committee to examine into the doings of a previous one.

T. Egleston.—I do not think there is any ambiguity or hinting in the matter. If there are words in the English language that can state plainly what the difficulty is, I think those words are contained in the report. The gist of the whole matter is this : I have had occasion to use that testing machine in making some investigations recently, and I went to Washington, to headquarters, to ascertain what the conditions were under which I could use it. I found every engineer officer and every government officer extremely anxious that the Commission should go on and do the work. I went back to New York and the several members of the Commission were also extremely anxious. I talked with Col. Laidley and found that he was extremely anxious. In the meantime I have found that certain members of Congress are extremely anxious that the work should be done. But when you come to look over that report you will find the Chairman of the Committee states positively that he could not report to the Ordnance Department, and that the Committee of this Society preferred that the whole thing should die without a motion in its behalf, rather than that they should report to the Ordnance Department. I think that is the short of it.

Mr. Boller's motion, as amended by Mr. Collingwood, was adopted.

The President.—The Chair will make the appointment and announce the names of the committee hereafter. (See page 40.)

J. J. R. Croes then reported verbally : The Committee on the Gauging of Streams has the honor to report that a considerable correspondence has taken place with members in various parts of the country who have been asked to make gaugings of the streams in their vicinity, and to send them to the Society for tabulation. No response has been received since the meeting in last November. At that time a paper was presented by Mr. Fteley, of Boston, on the gauging of the Sudbury river, which paper was discussed to some extent, and is now in print and will probably be issued in the next number of the Transactions. The work of the committee will be seen, to some extent, in that paper, and in the discussions upon it. Further papers on the same subject have been promised by Mr. Fteley and will be forthcoming probably in a month or two. The result of the applications for gaugings, sent to all parts of the country, has not been so satisfactory as the committee would desire. In very few instances have any responses been received at all, and these responses were to the effect that the parties applied to had not measured any streams at all. The committee ask to be continued.

On motion the report was accepted and the committee continued.

The Secretary asked if any member of the Society had any business to propose.

C. Latimer.—There has been heretofore a standing resolution on our

statutes that the metric measures be put upon the papers of this Society. I move that that resolution be rescinded.

The PRESIDENT asks for information.

The SECRETARY.—At the Ninth Annual Convention of this Society a resolution was passed that, thereafter in all papers written for the Society, members should include in such papers the dimensions in metric measure as well as in English feet and inches, and that this resolution should be published continuously in the Proceedings of the Society. It has been so published since that Convention.

T. G. ELLIS.—I would like to ask the Secretary whether any members have availed themselves of that resolution to put metric measures in any of their papers ?

The SECRETARY.—Two, I think, since I have been Secretary.

T. G. ELLIS.—Is there any other such standing resolution ?

The SECRETARY.—Not that I am aware of.

T. G. ELLIS.—I think under these circumstances it is not necessary to print it for the benefit of two papers in so many years. I think if it stands we should add the measures of other nations where we have more resident members than we have in the case of France. For instance, in Mexico and South America we have more resident members than we have in any other country whose metric system we are acquainted with.

T. EGLESTON.—The metric system is adopted in Mexico.

C. LATIMER.—That is true, and Mr. Wellington says it has produced such confusion that he does not know where he is. I have a letter from him to that effect.

A. P. BOLLER.—With regard to the motion rescinding the resolution it does not make much difference except to expunge from the record an inoperative resolution. There is nothing to prevent any member putting as many measurements into his paper as he chooses. The fact that only two papers have included metric measurements during Mr. Bogart's secretaryship shows that members do not regard this as a compulsory resolution, but one they can disobey at their own pleasure. As long as the resolution must be a dead letter, and we cannot compel members to abide by it, perhaps we had better expunge it from the record.

Mr. Latimer's motion was submitted to a vote, and adopted by 28 for, to 9 against.

The business meeting of the Convention was then adjourned.

OF THE BOARD OF DIRECTION.

JUNE 8TH, 1881.—Applications were considered. Action was taken in regard to the Building Fund and the Fellowship Fund.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
BLICKENSDERFER, JACOB	Chief Engineer Union Pacific R.R., Omaha, Nebraska	June 1, 1881
BRECKENRIDGE, CABELL	Engineer Alabama Great Southern R.R. Chattanooga, Tenn	" "
HAIGHT, STEPHEN S	West Farms, New York City, N. Y	" "
HARRIS, WM. P	Supt. New York and Greenwood Lake R. R., 37 Alling St., Newark, N. J	" "
MUNROE, HENRY S	School of Mines, Columbia College, New York City, N. Y	May 4, 1881
SYMINGTON, WILLIAM N	P. O. Box 2011, New York City, N. Y	" "
WHINERY, SAMUEL	(Elected Junior April 1, 1874,) Ass't. Eng'r. New Orleans and North Eastern R. R., Meridian, Miss	" "
WILDER, FRANCIS M	Sup't. M. P. Department N. Y. L. E. and W. Railway, Susquehanna Depot, Pa.	Jan. 5, 1881

ASSOCIATE.

GORRINGE, HENRY H	32 Waverly Place, New York City, N. Y	April 6, 1881

JUNIORS.

ALLAIRE, WILLIAM M	358 West Thirty-second St., New York City, N. Y	March 2, 1881

CHANGES AND CORRECTIONS.

MEMBERS.

BECKWITH, ARTHUR	115 Broadway, New York City, N. Y.
BECKWITH, L. F	115 Broadway, New York City, N. Y.
DOANE, EDWIN A	Chief Engineer R. W. & O. R. R., Oswego, N. Y.
ELLIS, N. W	33 Pine St., Room 19, New York City, N. Y.
FLAGG, J. FOSTER	Div. Engineer, Mexican National R. R., Manzanilla, Mexico.
FULLER, S. T	Chief Engineer Texas Mexican R. R., Houston, Texas.
GOLAY, PHILIP	Paducah, Ky.
HARRIS, ROBERT L	(Ross & Harris,) San Antonio, Texas.
NEILSON, CHARLES	Sup't. Delaware Div. N. Y., L. E. and W. Railway, Port Jervis, N. Y.
WALKER, JOHN S	Ass't. Engineer Mex. National Cons. Co., Laredo, Texas.
WARD, CHARLES D	Windsor Hotel, Jersey City, N. J.
WARD, LEBBEUS B	Windsor Hotel, Jersey City, N. J.

JUNIORS.

BROOKS, FRED'K.....Office Mexican Central Railway, Mexico, Mexico.
CURTIS, WENDELL R ....California Southern R. R., San Diego, Cal.
FERGUSON, JOHN W.....Ass't. Engineer N. Y., L. E. and W. Railway, Hornelsville, N. Y.

FELLOWS.

DILLON, SIDNEY .....President Union Pacific R. R., 78 Broadway, New York City, N. Y.
NORTON, F. O.....92 Broadway, New York City, N. Y.
SEYMOUR, M. T.....55 Broadway, New York City, N. Y.

DEATHS.

WEBER, M. M. BARON VON.,Elected Honorary Member June 2, 1880. Died April 18, 1881.
HALL, G. THOMAS .....Elected Associate October 2, 1872, and transferred to Member September 2, 1874. Died June 2, 1881.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—July, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

JULY 6TH, 1881.—The Society met at 8 P. M., Vice-President Welch in the chair. Ballots were canvassed and the following candidates declared elected:—As Members, Oliver Weldon Barnes, New York City; William Anderson May, Scranton, Pa.; James Gardner Sanderson, Scranton, Pa.:—As Associate, Henry Robert Bradbury, New York City. The Norman Medal for the last year was formally presented to Theodore Cooper, M. A. S. C. E.

ADDITIONS TO

LIBRARY AND MUSEUM.

From S. Thayer Abert, U. S. C. E. Washington, D. C.:

Annual Report on Improvement of Rivers and Harbors in District of Columbia, Maryland, Virginia and North Carolina. S. Thayer Abert.

From Administration des Ponts et Chaussées, Paris:

Annales. February, March, April and May, 1881. List of Members, 1881.

From American Academy of Arts and Sciences. Boston:

Proceedings. Vol. VIII., New Series, Part I., May, 1880 to February, 1881.

From American Chemical Society, New York:

Journal of the Society. Vol. II., Nos. 8-12, August, December, 1880.

From American Institute of Mining Engineers, Dr. T. M. Drown, Secretary, Easton, Pa.:

Proceedings of the Annual Meeting held in Philadelphia, February, 1881.

The Gold-Bearing Mispickel Veins of Marmora, Ontario, Canada. R. P. Rothwell.

The Whopper Lode, Gunnison County, Colorado. Prof. Persifor Frazer.

Steel for Bridges. J. W. Clowd.

The advance in Mining, Metallurgical Art. Science, and Industry since 1875. W. P. Shinn.

Shocks on Railway Bridges. J. W. Clowd.

The Industrial School for Miners and Mechanics at Drifton, Luzern Co. Pa. O. J. Heinrich.

Gas Producers using Blast. F. H. Daniels.

Effect of Sewage on Iron. C. O. Thompson.

The Construction on Geological Cross-sections. H. Martyn Chance.

Ore Roasting Furnace. W. J. Taylor.

Note on the Estimation in Speise. F. C. Blake.

Method for the Estimation of Manganese in Spiegels, Irons and Steels. S. A. Ford.

Note on a Direct Process for Treating fine Iron Ores. W. E. C. Eustis.

A Fluxing Gas Producer for making Heating Gas. W. J. Taylor.

The Amount of Manganese Required to remove the Oxygen from Iron after it has been blown in a Bessemer Converter. S. A. Ford.

Notes on the Assay Spitzlutte. R. H Richards.

On the Applicability of Edison's System of Electric Lighting to Mines. O. A. Moses.

A new Bottom for Bessemer Converters. C. F. Manness.

Auriferous Slate Deposits on the Southern Mining Region. P. F. Mell, Jr.

Can the Magnetism of Iron and Steel be used to Determine their Physical Properties? Wm. Metcalf.

On the action of Common Salt and other Crystalline Salts in Wire-Drawing. C. O. Thompson.

On Rail Patterns. A. L. Holley.

From American Iron and Steel Association. James M. Swank, Secretary, Philadelphia:

Preliminary Report upon the Iron and Steel Industries of the United States in the Census year 1880, ended May 31, 1880. James M. Swank. Philadelphia, 1881.

From Argentine Scientific Society. Don Eduardo E. Clerice, Secretary, Buenos Ayres:

Annales. February, March and April, 1881.

From Arthur Beardsley, Bethlehem, Pa.:

Register of the Lehigh University, 1880-1881.

From Thomas J. Bell, Cincinnati:

Forty-first Annual Report of the Water Department of Cincinnati.

From Charles E. Billin, Indianapolis, Ind.:

Proceedings of the Convention of Engineers and Surveyors of the State of Pennsylvania, held at Harrisburg, Pa., Oct. 27th, 28th and 29th, 1881 (*Copies for distribution*).

From Boston Society of Civil Engineers. S. E. Tinkham, Secretary, Boston:

Proceedings, April, 1881. Annual Meeting of the Society, March, 1881.

Annual Report of the Government.

The Back Bay Park. E. W. Howe.

From Boston Public Library, Boston:

Bulletin of the Library. April, 1881, Vol. IV., No. 10.

From G. Bonscaren, Cincinnati:

Instruction for Laying out Circular Curves with Special Approaches. G. Bonscaren. (Several copies).

From Lyman Bridges, San Francisco:

Report on the San Francisco and Ocean Shore Railroad Co., California. New York, 1881.

Report on the California Central Railway in California and Nevada. New York, 1881.

From L. L. Buck, Brooklyn, N. Y.:

Report on the Renewal of Niagara Suspension Bridge. L. L. Buck. New York, 1881 (2 copies).

From Bureau of Education, Washington, D. C.:

Report of Commissioner of Education for 1878.

Library Aids. Samuel S. Green.

Comparative Statistics of Elementary Education in Fifty Principal Countries.

From H. M. Chance, Philadelphia:

The Construction of Geological Cross-sections. H. M. Chance, M. D., Philadelphia, 1881.

From M. A. Durand-Claye, Paris:

Les Eaux d'Egout. A. Durand Claye, Paris, 1880

Les Travaux d'Assainissement de Danzig, Berlin, et Breslau. A. Durand Claye, Paris, 1881.

From Wm. B. Cogswell, Syracuse, N. Y.:

The Credit Mobilier of America. Rowland Hazard, Providence, 1881.

From John Collet, Chief of Bureau of Statistics and Geology of Indiana, Indianapolis:

Second Annual Report of Department of Statistics and Geology of Indiana.

From Jörgen Dahl, Norway, Sweden :
Types of Construction on the Norwegian Railways of 3 feet 6 inches gauge.

From Thomas M. Drown, Easton, Pa. :
An Address at the Reopening of Pardee Hall, Lafayette College, 1881, Easton, Pa.

From C. E. Durkee. Albany, N. Y. :
Report on Routes and Estimates. Sacketts Harbor and Saratoga Railroad. Saratoga Springs, 1852.
The Adirondack Railroad and Estate. New York, 1873.

From Engineers' Club of Philadelphia, Howard Murphy, Cor. Secretary, Philadelphia :
Proceeding, Vol. II., No. 2.

From Engineers' Department, U. S. A. Washington, D. C. :
Official Army Register, January, 1881.
Lecture on the Progress of the Works of Completion of the new Improved Bed of the Danube at Vienna, by Sir Gustav von Wex. Translated by Gen. G. Weitzel, U. S. A.
Annual Report of the Chief of Engineers, U. S. A. Parts I., II., III., 1880.
The Water-jet as an Aid to Engineering Construction. L. Y. Schermerhorn, Washington. 1881.
Contribution to the Theory of Blasting or Military Mining. H Höler. Translated by C. W. Raymond. Washington. 1881.
Specifications for Dredging in Inner Harbor at Michigan City, Indiana. Maj. J. A. Smith.
Specifications for Constructing Dams and Shore Protections of Brush and Stone, at Andalusia, Ill. Capt. A. Mackenzie.
Specifications for Dredging in the Galena River, Ill. Capt. A. Mackenzie.
Specifications for Building a Wing-Dam at Glastonbury Bar. on the Connecticut River. Gen. G. K. Warren.
Specifications for Improvement of Rancocas River, N. J. Col. J. N. Macomb.
Specifications for Rip-Rap for Jetties at the Mouth of Connecticut River. Gen. G. K. Warren.
Copies of Reports submitting plans for the Improvement of the Mouth of Columbia River. Colonel G. L. Gillespie.
A Report relative to devising a system of works to prevent the further injury of the navigable waters of California from the débris of mines arising from hydraulic mining. Col. G. H. Mendell.
A copy of the Report of the Board of Engineers examining the several points on the Pacific coast for the purpose of locating a harbor of refuge, and especially that relating to Port Orford, Oregon.
A Communication and Report upon the results obtained from the surveys and examinations of the season of 1880, for the establishment of Reservoirs at the headwaters of the Mississippi River and the sources of certain streams in Wisconsin and Minnesota, including Rock River, Wisconsin and Illinois. Capt. J. C. Allen.
The report of the Mississippi River Commission. (*Copies for distribution.*)
Specifications, Advertisement, Proposals, and Bidder's Bond for Improving Chicago Harbor. Maj. G. J. Lydecker.
Advertisement. Ohio River Improvement. Proposals for Iron Work at the Davis Island Dam. Col. Wm. E. Merrill.
Specifications for Dredging in Winnepissiogee Lake, New Hampshire. Gen. Geo, Thom.
Specifications for Breaking up and Removing Sunken Ledges in Merrimac River, Mass. Gen, Geo. Thom.
Specifications for Excavation of Sunken Ledges at the "Gut," opposite Bath, Me. Gen. Geo. Thom.
Specification for Dredging and Building a Rubble-stone Wing-dam in Kennebec River, at and near Richmond, Maine. Gen. Geo. Thom.

Specifications for the Construction of the Breakwater on the Saint Croix River, near Calais, Maine. Gen. Geo. Thom.
Advertisement. Instructions, Specifications and Proposals for Improving Harbor at Menomoull (Mich. and) Wis. Maj. Henry M. Robert.
A Communication accompanying copy of Report upon the Survey of the Reopening of the Santee Canal, South Carolina. Gen. Q. A. Gillmore.

From Charles E. Fowler, New Haven, Ct. :
City Year Book of New Haven. 1880.
Annual Report of the Street Department of New Haven for 1880.
Public Parks : A Lecture by Simon E. Baldwin.

From Robert Gordon, Henzada, British Burmah :
Fragment containing a Discussion of a New Formula for Flow of Water in open Channels. Robert Gordon. Milan, 1875.
On the Theory of the Flow of Water in Open Channels, Robert Gordon. Rangoon. 1875.

From Geo. S. Greene, Jr., New York :
Annual Report Department of Docks, City of New York for 1880. (2 copies.)

From John W. Hill, Cincinnati :
Report of the Expert on the Contract Trials of the Gaskill Compound Pumping Engine at the Evansville Water Works. J. W. Hill, Cincinnati. 1881.

From E A. Hill, New Haven, Ct.:
Annual Report of the Boston & New York Air Line Railroad Company from 1878 to 1881, inclusive.
Statutes of the State of Connecticut relating to Railroads. Hartford. 1878.
The Hayford Process and Apparatus for Preserving Timber. E. R. Andrews. Philadelphia. 1878

From Institution of Civil Engineers, James Forrest, Secretary. London :
Minutes of Proceedings Vol. LXIII.

From M. E. Lavoinne, Paris :
The Purification of Memphis. St. Germain. 1881 (French),

From Massachusetts Institute of Technology, Boston :
Sixteenth Annual Catalogue of the Institute. 1881.

From A. G. Menocal, C. E., U. S. N., Washington, D. C.:
Transportation of Ships on Railways. Some of the difficulties presented. S. L. Phelps. Washington, 1881.

From Dr. W. H. McFadden, Philadelphia :
Annual Report of the Philadelphia Water Department for 1880. Philadelphia. 1881.

From Midland Institute Mining, Civil, and Mechanical Engineers, Barnsley, England :

Transactions. December, 1880. February, 1881.

From Edward Mitchell, New York :

Seventh Annual Report on the Progress of of the Topographical Survey of the Adirondack Region of New York. Verplanck Calvin. Albany, N. Y.

From Charles Neilson, New York :

Effect of the Motion of Air within an Auditorium upon its Acoustic Qualities. W. W. Jacques.

The History and Description of the Great Western Railway. John C. Bourne. London, 1856.

From Gen. John Newton, New York :

Report on a general scheme of Improvements for the Harbor of Montreal. by the Commission of Engineers. Mr. Robert B. Bell, Maj. Gen. John Newton, and Mr. Sandford Fleming. Montreal. 1877.

From North of England Institute Mining and Mechanical Engineers, New Castle-on-Tyne, England :

Transactions. December, 1880 – February, 1881.

From Charles Paine, Gen. Supt. L. S. and M. S. Railway, Cleveland :

Eleventh Annual Report of the Lake Shore and Michigan Southern Railway Co. Cleveland. 1881.

Special Report of the Commissioner of Railroads and Telegraphs of Ohio. Columbus. 1881.

Reports of the Great Western Railway of Canada, from 1870 to 1880, inclusive.

From the Pi Eta Scientific Society, Troy, N. Y., 1881 :

Papers read before the Society :

The Chamber of Bridges, T. M. Cleeman.

The Inter Oceanic Canal. W. E. Dauchy.

Bridge Pins—Their Sizes and Bearings. J. A. L. Waddell.

Rational Fractions. A. E. Besosa.

Note on Gordon's Formula on Long Columns. W. H. Burr.

The size of an Angle Block in a Howe Truss Bridge. T. M. Cleeman.

Discussion of Paper on "Braced Iron Piers." W. H Burr.

From Wm. Rotch, Boston, Mass.:

Annual Report of the Mexican Central R'y. Co. (Ld.), year ending December 31, 1880. Boston. 1881.

Report on the Case of the Watuppa Reservoir Co. *vs.* The City of Fall River. Wm. Rotch, C. E., December, 1880. Fall River. 1881.

From Saxonian Society of Engineers and Architects, Leipsic :

Transactions. 2d half. 1880.

From School of Mines, Columbia College, New York :

School of Mines Quarterly. Vol. II., No. 8.

From Hon. Horatio Seymour, Jr., State Engineer and Surveyor, Albany, New York :

Prosperity of our Canals. Horatio Seymour, Jr. Albany, 1881.

From W. W. C. Sites, Jersey City, N. J.:

Annual Report of the Chief Engineer of the Department of Public Works of Jersey City, N. J. Jersey City. 1881. (2 copies.)

From Smithsonian Institution, Washington, D. C.:

Annual Report for 1879.

From Society of Engineers, Bartholomew Reed, Secretary, London :

Transactions. 1880.

From Society des Ingeniéurs Civils, Paris :

Memoires, February, 1881.

From Treasury Department, Washington :

Statistical Abstract of the United States, 1880.

Third Number. Finance, Coinage, Commerce, Immigration, Shipping, The Postal Service, Population, Railroads, Agriculture, Coal and Iron, etc.

From United States Naval Institute, Annapolis, Md.:

Proceedings Vol. VI., No. 14.

From M. M. Frhrm von Weber, Berlin:

Studie über die Wasserstrassen Schwedens. M. M. Frhrm von Weber. Berlin. 1880.

From Western Society of Engineers, L. P. Morehouse, Secretary, Chicago:

Proceedings. Vol. V.

From Other Sources :

A List of Railroads, Canals and Ferries owned, leased, operated and controlled by the Pennsylvania Railroad Co. on December 31st, 1880

Arguments of Mr. E. P. Wheeler, before Assembly Committee on Cities, on Underground Telegraph Wires in Cities. New York. 1881.

Annual Report Department City Works of Brooklyn, N. Y., for 1880.

The Library Journal, Vol. VI., No. 14.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

BARNES, OLIVER W.....57 Broadway, New York City, N. Y.....July 6, 1881

GLASKIN, EDWIN E.....(Elected Junior April 5, 1876,) 52 Queen Victoria Street, London, England ....May 4, 1881

SANDERSON, J. GARDNER..115 Broadway, Room 80, New York City, N. Y.....July 6, 1881

ASSOCIATE.

BRADBURY, HENRY R.....Manager Neuchatel Asphalte Co. (Ld.), 54 Astor House, New York City, N. Y. July 6, 1881

CHANGES AND CORRECTIONS.

MEMBERS.

BROWN, CHARLES O.. ....Civil Engineer and Contractor, 52 & 54 William Street, New York City, N. Y.

BUCK, L. L.....Central Railroad of New Jersey, 119 Liberty Street, New York City, N. Y.

CHITTENDEN, SAMUEL H..East River, Conn.

DAVIS, CHARLES E. L. B..Capt. Corps of Engineers U. S. A., Sabine Pass, Texas.

ENDICOTT, M. T.....Civil Engineer U. S. N., Navy Yard, League Island, Pa.

FLAGG, J. FOSTER... ....Div. Engineer Mexican National R. R., Colima, Mexico.

LATCHA, JACOB A.....Chief Engineer New York, Chicago and St. Louis R.R., 32 Board of Trade, Cleveland, Ohio.

NORTH, EDWARD P.....Chief Engineer Sinaloa and Durango R. R., Culiacan, Mexico.

SMITH, WM. SOOY.....Hudson River Tunnel, Jersey City, N. J.

SWEET, CHARLES A.....Mexican Central R. R., Durango, Mexico.

ASSOCIATE.

BELCHER, GEORGE W. C. . 2646 Washington Ave., St. Louis, Mo.

JUNIOR.

EMONTS, WILLIAM A. G. . . Huntington Valley, Bucks Co., Pa.

DEATH.

ROBERTS, W. MILNOR. . . . . (*Past President,*) Elected Member September 21, 1870. Died July 14, 1881.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—August, 1881.

NOTE.—No meetings of the Society are held in August.

CONTRIBUTIONS TO THE BUILDING FUND.

By a resolution of the Board of Direction, all contributions to the Building Fund are to be acknowledged, from time to time, by printing lists of the same in the monthly Proceedings of the Society, and in addition to this the names of all those who may subscribe $100 or more are to be regularly enrolled and published in future lists of the Society under the head of Subscribers to the Building Fund, and they will be entitled to receive one copy of the monthly publications, comprising all papers and transactions of the Society, regularly for life, for each $100 subscribed by them; such copies to be in addition to those which they may be already entitled to if they are Members or Fellows.

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From Charles L. McAlpine, New York :

Geological Report for St. Clair Railroad and Coal Company. J. P. Lesley. New York. 1855.

Annual Report of the State Engineer and Surveyor of the State of New York. Albany. 1851.

Annual Reports of the Chicago and Rock Island Railroad Company. New York. 1857 and 1859.

An Act to Incorporate the Woodstock and Lake Erie Railway and Harbor Company. Woodstock, C. W. 1852.

Documents submitted to the Galena and Chicago Union Railroad Company in relation to the Leasing of the Chicago, Fulton and Mississippi Railroad Bridge at Fulton. Chicago. 1858. (2 copies.)

Annual Report of the Baltimore and Ohio Railroad Company. Baltimore. 1859. (2 copies.)

First Annual Report of the London and Port Stanley Railway Company. London, C. W. 1854.

Articles of Agreement between the Corning and Olean Railroad Company and the New York and Erie Railroad Company.

Robert D. Silliman *vs.* The Hudson River Bridge Company at Albany ; F. W. Coleman *vs.* The same Defendant. In the Supreme Court of the United States for the Northern District of New York.

Annual Reports of the Railroad Corporations in the State of Massachusetts for 1852.

Catalogue of the Library of the Young Men's Association of Chicago. Chicago. 1856.

Annual Report of the Commissioners of the Canal Fund. Albany. 1848 and 1860.

Oswego and Syracuse Railroad. Freight Tariff. Utica. 1852.

Annual Meeting and Report of the Great Western Railroad. Hamilton, C. W. 1852 and 1853.

Report of the Hannibal and St. Joseph Railroad. Boston. 1859.

Report on Surveys for the Pictou Branch Railway, with some Remarks on the Trunk Line. James Laurie. Halifax. 1860.

Annual Report of the Department of the City of Baltimore to the Mayor and the City of Baltimore. Baltimore. 1860.

Report of the Pacific Railroad. San Francisco. 1866.

Report of the New York and Erie Railroad. New York. 1856.

A Memoir upon Stephenson's Silver Mine. J. M. Sprague. Albany. 1858.

Address to the Government of the United States upon the Merits of Pirsson's Patent Steam Condenser. Washington. 1860.

Statement of the Trustees and the Scientific Council of the Dudley Observatory. Albany. 1858.

Report on the Position of the Prospect Hill Engine House. New York. 1858.

Annual Report of the Board of Water Commissioners of the City of Detroit. Detroit. 1856 and 1857. (3 copies.)

Report of the Water Board of Georgetown, D. C. Washington, D. C. 1860.

Report and Plan of Sewerage of the City of Chicago. Chicago. 1855. (2 copies.)

Report of the Engineer to the Commissioners of Sewerage of the City of Brooklyn. Brooklyn. 1859.

Annual Review of the Trade and Commerce of the City of Chicago. Chicago, Ill. 1859.

The Cleveland *Herald's* First Annual Statement of the Trade and Commerce of Cleveland for 1858.

Report upon a Water Supply for the City of Baltimore. Baltimore. 1854.

Report of the Water Commissioners of the City of Albany. Albany. 1850. (2 copies.)

Report of the Engineers to the Commissioners of Drainage of the City of Brooklyn. Brooklyn. 1857.

Map of the Mississippi and Rock River Junction and Lyons Iowa Central Railroad.

Military Reconnaissance of the Arkansas, Rio del Norte and Rio Gila. W. H. Emory. 1847.

Rates of Toll per 100 pounds of the New York and Erie Railroad. May, 1857.

Plan of the Grand Junction Railroad. 1848.

Map of the various Channels for Conveying the Trade of the North-west. 1852

From Isaac Newton, New York :

Proceedings of the Baltimore Meeting of the American Institute of Mining Engineers. February, 1879.

The American Bloomary Process for Making Iron direct from the Ore. T. Egleston.

New Determination of the Coefficients of Friction and Lubricated Journals, and on the Laws Governing such Friction. R. H. Thurston.

Notes on the Result of an Experiment with the Wheeler Process of Combining Iron and Steel in the Head of a Rail. W. E. C. Coxe.

Experiments on the Removal of Carbon Silicon and Phosphorus from Pig Iron by Alkaline Carbonates. T. M. Drown.

The Mesozoic Formation in Virginia. O. J. Heinrich.

Improved Pipe and Tenyere. J H. Hartman.

The Wheeler Process for Welding Iron and Steel without the use of Fluxes. D. Torrey.

The Chemical Composition and Physical Properties of Steel Rails. C. B. Dudley.

Thin Plates of Metal. T. Egleston.

Does the Wearing Power of Steel Rails increase with the hardness of the Steel. C. B. Dudley.

The Production of Charcoal for Iron Works. J. Birkinbine.

Note on a Deposit of Cadmia in a Coke Furnace. H. Firmstone.

The New River Coal Field of West Virginia. F. S. Morris.

An Improved Universal Suspended Hydraulic Lift. J. A. Herrick.

The Manufacture of Soda by the Amonia Process. O. J. Heinrich.

The Jenks Corundum Mine, Macon County, N. C. R. W. Raymond.

A Catalogue of Official Reports upon Geological Surveys of the U. S. and Territories and of British North America. F. Prime, Jr.

Note on the Defreest Journal-Bearing. J. C. Platt, Jr.
The Law of Fatigue and Refreshment of Metals. T. Egleston.
The Tessie Gas Producer. A. L. Holley.
Accidents in the Comstock Mines, and their Relation to Deep Mining. J. A. Church.
On the use of determining Slag Densities in Smelting. T. Macfarlane.
The Mechanical Work Performed in Heating the Blast. Prof. P. W. Frazier.
The Heat of the Comstock Mines. J. A. Church.
Proceedings of the Meeting of the American Inst. Mining Engineers, at Lake George and Lake Champlain.
On some Curious Phenomena observed in making a Test of a Piece of Bessemer Steel. Wm. Kent.
Proceedings of the Pittsburgh Meeting of the American Inst. Mining Engineers.
Note on the Wear of an Iron Rail. E. C. Coxe.
The U. S. Testing Machine at Watertown Arsenal. A. L. Holley.
The Antimony Deposits of Arkansas. C. E. Wait.
The Working of Three Hearths at the Cedar Point Furnace, Port Henry, N. Y. T. F. Witherbee.
On the Apparatus for Testing the Resistance of Metals to Repeated Shocks. Wm. Kent.
Pittsburgh—Its Resources and Surroundings. Wm. P. Shinn.
Sketches of the New Mining District at Sullivan, Maine. C. W. Kempton.
Regenerative Stores—A Sketch on their History and Notes on their Use. J. M. Hartman.
The Coal and Iron of the Hocking Valley, Ohio. T S. Hunt.
Discussion of Dr. C. B. Dudley's Papers on Steel Rails, read at the Lake George Meeting, October, 1877.
A New Method of Dredging, Applicable to some kind of Mining Operations. R. W. Raymond.
The Nickel Ores of Oreford, Quebec, Canada. E C. Eustis.
Notes upon the Drainage of a Flooded Ore pit at Pine Grove Furnace, Pa. John Birkinbine.
Manganese Pig. Dr. R. W. Raymond.
On The Manufacture of Artificial Fuel at Port Richmond, Philadelphia. E. F. Loiseau.
A Method of Rolling Steel or Iron Eye Bars. Chas. Macdonald.
The Pernot Furnace. A. L. Holley.
The Fire-Clays and Associated Plastic Clays
Kaolins, Feldspars and Fire Sands of New Jersey. Prof. J. C. Smock.
The Economy Effected by the use of Red Charcoal. B. Fernow.
Note upon the Cost of Construction of the Converting Works at the Edgar Thompson Steel Company of Pittsburgh, Pa. P. Barnes.
On the Use of Red Charcoal in the Blast Furnace. Wm. Kent.
A New Air Compressor. E. G. Spilsbury.
The Late Operations on the Mariposa Estate. C M. Rolker.
The Strength of Wrought Iron as Affected by its Composition and by its Reduction in Rolling A. L. Holley.
The Manhattan Salt Mine, at Godrich, Canada. O. J. Heinrich.
Fluxing Silicious Iron Ores. T. F. Witherbee.
Memorandum Relating to the Construction Account of the Rail Mill of the Edgar Thompson Steel Company, Pittsburgh, Pa. P. Barnes.
A New Method of taking Blast Furnace Sections. T. F. Witherbee.
Memoranda showing the Percentage of the Different Expense Accounts in Mining Hematite Ore at the Manhattan Mine, Sharon Station, New York. F. J. Lewis.
Improvements in the Appliances for Venting Molten Steel or Iron from a Casting-Ladle or Shoe. J. A. Herrick.
New Steam Engine Indicator. J. E. Sweet.
Phosphorus in Coal. Andrew S. McCreath.
Note on the Determination of Silicon in Pig Iron and Steel. Dr. T. M. Drown.
Experiments with Charcoal, Coke and Anthracite, in the Pine Grove Furnace, Pa. John Birkinbine.
Relation of Sulphur in Coal and Coke. Dr. J. B. Kimball.
On the Classification of Original Rocks. T. Macfarlane.
Notes on the Zinc Deposits of Southern Missouri. R. W. Raymond.
A Direct Process of Copper Smelting. H. M. Howe.
Washing Phosphoric Pig Iron for the Open-Hearth and Puddling Processes, at Krupp's Works, Essen. A. L. Holley.
The Hygiene of Mines. R. W. Raymond.
Proceedings of the Montreal Meeting, of the American Inst. Mining Engineers, September, 1879
The Cost of Milling Silver Ores in Utah and Nevada. R. P. Rothwell.
Recent Improvements in Concentration and Amalgamation. J. E. Church.
An Autographic Transmitting Dynamometer. Wm. Kent.
Silver Islet. T. MacFarlane.
The Humboldt-Pocahontas Vein, Rosita, Colorado. R. N. Clark.
The Great Blast at Glendon. E. Clark, Jr.
The Lake Superior Copper Rocks in Pennsylvania. J. F. Blandy.
The Bradford Oil District of Pennsylvania. Chs. A. Ashburner.
An Improved System of Cornish Pitwork. E. Dagget.
Annual Report of the Engineer and Surveyor of the State of New York, of the Railroad Corporations.
Returns of the Railroad Corporations in Massachusetts. 1866.
Fourth and Fifth Annual Reports of the Board of Railroad Commissioners of Massachusetts
Second Annual Report of the Board of Health of the City of New York.
Sixteenth Annual Report of the Chamber of Commerce of the State of New York.
Public Papers of John T. Hoffman, Governor of New York.
Message of the President of the United States and Accompanying Documents, to the Two Houses of Congress, at the Commencement of the First Session of the Thirty-eighth Congress.
Annual Report of the Commissioners of Patents for the Year 1867.
Statistics of Mines and Mining in the States and Territories West of the Rocky Mountains. R. W. Raymond.

Historical View of the Art of Electro-Magnetic Telegraphing in connection with the Telegraph Cable and its insulation by Gutta Percha.
Argument of Franklin B. Gowan, Esq., before the Joint Committee of the Legislature of Pennsylvania.
Transactions of the American Philosophical Society. Vol. XII. Part III.
The Imperial Cyclopædia of Machinery.
The Woodruff Scientific Expedition Around the World. 1877–9.
The Empire of Brazil at the Universal Exhibition of 1876, in Philadelphia.
Catalogue of the Officers and Students of Columbia College. 1869–1870. 1876–77.
Catalogue of Columbia College School of Mines. 1868–69.
Catalogue of Columbia Academic Department. 1872–73.
Sixteenth Annual Register of the Free Academy of the City of New York.
Seventeenth Annual Register of the Free Academy of the City of New York.
Twenty-second Annual Register of the College of the City of New York.
Merit Roll of the New York Free Academy, First Academic Term.
Oration and Poem Delivered Before the Associate Alumni of the College of the City of New York.
Address of the Associate Alumni of the Board of Trustees of the College of the City of New York.
Historical Cabinet of the College of the City of New York.
Thirty-fifth Annual Catalogue of the Officers, Faculty and Students of the University of Notre Dame, Indiana.
Catalogue of the Officers and Students of Lafayette College. 1871–72. 1872–73.
Annual Catalogue of the Officers and Students of Hamilton College. 1872–73.
Charter, Constitution and By-Laws of the Lyceum of Natural History in the City of New York.
By-Laws of the Lyceum of Natural History of the City of New York.
List of Officers, Honorary Members, Members and Associates of the American Chemical Society.
Silver as a Commodity, as Money and as a Material for Token Coins or Fractional Currency. Hon. Wm. D. Kelley.
Royal College of Science for Ireland. Syllabus of a Course of Lectures on Botany.
Science and Art Department, Royal College of Science for Ireland. Programme of the Educational Arrangements. 1870–71.
Annual Report of the Chief Engineers U. S. A. for 1875. Parts I and II.
The Legislative Manual of the State of New York for 1861.
The Correlation and Conservation of Forces. A Series of Expositions. Edited by Edward L. Youmans.
Davies' Surveying. New York. 1841.
The Marine Steam-Engine. Thos. J. Main and Thos. Brown.
An Elementary Course of Civil Engineering. D. H. Mahan.

From R. E. Peary, Washington, D. C.

Message from the President of the United States in response to Senate Resolution of February 11, 1880. Covering report of Secretary of State; with accompanying documents in relation to the proposed Inter-oceanic Canal between the Atlantic and Pacific Oceans.
Message from the President of the United States, transmitting copies of correspondence in relation to the Inter-oceanic Canal. March, 1881.
Letter from the Secretary of the Navy, with the report of Rear-Admiral Davis on Inter-oceanic Communication at the American Isthmus.
Speech of Hon. Wm. Windom, of Minn., in the Senate of the United States, on Isthmus Ship Canals, February 28, 1881. Washington, 1881.
Report of Mr. King, from the Committee on Inter-oceanic Ship Canal. February, 1881, on Inter-oceanic Ship Railway.
Report of Mr. Oscar Sumer, from the Select Committee on Inter-oceanic Ship Canal, submitted February 17, 1881, on Tehuantepec Ship Railway.
Review of Capt. Phelps' Pamphlet, entitled Transportation Ships on Railways. Capt. Jas. B. Eads.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

Date of Election.

ATWOOD, WILLIAM H.....Res. Engineer, New York, Lake Erie and Western R.R., Jersey City, N. J.....May 4, 1881
BLICKENSDERFER, ROBERT. Div. Engineer Utah and Northern Railway, Terminus, Montana..... .. ...June 1, 1881
MAY, WILLIAM A.....Box 173, Scranton, Pa.....July 6, 1881
WELLINGTON, ARTHUR M. Locating Engineer Mexican National Railroad, Mexico, Mex.....May 4, 1881

JUNIOR.

STEWART, HUNTER.....2828 Washington Ave., St. Louis, Mo.....June 1, 1881

CHANGES AND CORRECTIONS.

MEMBERS.

BECKER, M. J.....Chief Engineer P., C. & St. L. R.R., Pittsburg, Pa.
BRUNER, D. P.....P. O. Box 4, Allegheney City, Pa.
CHESBROUGH, E. S.....Dept. Public Works, 31 Chambers St., New York City, N. Y.
CORTHELL, E. L.....Chief Engineer N. Y., W. S. & B. R.R., 20 Nassau St., New York City, N. Y.
ELLIS, N. W.....Box 53, Manchester, N. H.
GARDNER, G. CLINTON....Gen. Man. Mexican National R.R., 47 William St., New York City, N. Y.
HARDING, HENRY.....Maverick House, East Boston, Mass.
HARRIS, WILLIAM P.....Supt. N. Y. & G. L. R.R., Jersey City, N. J.
LEHNARTZ, F. H.....(Stockder & Lehnartz), Lake City, Col.
LEVERICH, G.....Box 174, South Orange, N. J.
MCKEE, CHARLES H.....D. & H. C. Co. R.R., French Mountain, N. Y.
MCLAIN, LOUIS R.....Div. Engineer G. & P. R.R., Oxford, Ala.
PAINE, CHARLES.....Gen. Man. N. Y., W. S. & B. R.R., 20 Nassau St., New York City, N. Y.
STANTON, ROBERT P.....Div. Engineer U. P. R.R., Union Depot, Denver, Col.

ASSOCIATE.

HARRIS, CHARLES M.....Care Parsons & Co., 42 Pine St., New York City, N. Y.

JUNIORS.

BROOKS, FREDK.....Mexican Central Railway, Tampico, Mex.
BUTTS, EDWARD.....P. O. Box L, Kansas City, Mo.
HORTON, SANFORD.....48 Carroll St., Poughkeepsie, N. Y.
LUCAS, D. JONES.....Corry, Pa.
RAYMOND, CHAS. WARD..269 West Eleventh St., New York City, N. Y.

DEATHS.

RENO, JAMES H.....Elected Member, Nov. 5, 1879. Died Aug. 5, 1881
FARGO, WILLIAM G..... " Fellow, May 6, 1870. " " 4, 1881

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—September, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

September 7th, 1881.—The Society met at 8 p. m., Director William H. Paine in the chair. Ballots were canvassed, and the following candidates declared elected:—As members, Charles Blackwell, Ottawa, Canada; Walter A. Doane, Meadville, Pa.; Robert L. Engle, Cincinnati, Ohio; Charles Edward Goad, Montreal, Canada; Arthur Hider, St. Louis, Mo.; William Pierson Judson, Oswego, N. Y.; Louis Lesage, Montreal, Canada; Alexander Ludus Light, Quebec, Canada; Theodore H. McKenzie, Southington, Ct.; Gilbert Murdoch, St. Johns, New Brunswick, Canada; Etienne Henri Parent, Montreal, Canada; George Steele Skilton, Mexico, Mexico. As Associate, John Strathearn Hendrie, Marquette, Mich.

The death was announced of William Milnor Roberts, Past President of the Society, which occurred in Brazil, South America, July 14th, 1881; also the death of G. Thomas Hall, Member of the Society, which occurred in New York, June 2d, 1881; also the death of James H. Reno, Member of the Society, which occurred in Pittsburgh, Pa., August 5th, 1881; also the death of William G. Fargo, Fellow of the Society, which occurred in Buffalo, N. Y., August 4th, 1881. The appointment of Committees to prepare in each case a memoir for publication, was authorized.

A paper by D. McN. Stauffer, Member A. S. C. E., subject, Shaft Sinking under difficulties at Dorchester Bay Tunnel, Boston, Mass., was presented and its discussion postponed until the next meeting.

OF THE BOARD OF DIRECTION.

August 9th, 1881.—Applications were considered. Appropriations were made.

September 6th, 1881.—Applications were considered.

MEMOIRS OF DECEASED MEMBERS.

JAMES A. HAYWARD, Member A. S. C. E.

Died August 13th, 1880.

James A. Hayward was born in Dublin, New Hampshire, September 12th, 1849. He spent some time, when quite young, at Antioch College, Ohio, and in 1870 graduated with honor as a Civil Engineer at the University of Michigan. He was engaged in map business during a part of the time, from 1870 to 1873, in which latter year he married Miss Ida Upjohn, of Kalamazoo, Michigan. His wife and child died in 1876. In 1873 Mr. Hayward entered the United States service as U. S. Assistant Engineer on the survey of Pass Cavallo, entrance to Matagorda Bay and Channel to Indianola. In December, 1873, he was placed in charge of the portion of the survey for a canal to connect the inland waters along the Gulf of Mexico from the Mississippi River to the Rio Grandé, extending from Donaldsonville to Vermillion Bay, La.

After this survey was completed and estimates made he was employed in the U. S. Engineer office in New Orleans, at various duties, and for a short time assisted in taking cross-sections of South Pass, Mississippi River. He was thus employed until March, 1875, when he left the service and returned to Michigan. In November, 1876, he was placed in charge of the survey of a ship channel through Galveston Bay and was afterwards continued in the government employ in charge of the surveys of Sabine Pass, Texas, and as inspector of dredging at the mouth of the Neches River. He was accidentally drowned from the schooner Amadeo, August 12th, 1880, upon which vessel he was making a trip down the west coast of the Gulf of Mexico.

Mr. Hayward leaves a widowed mother and a sister. His professional life had been confined to the duties connected with the United States Engineer service, and his early death has cut off a member of the profession who gave great promise of enlarged usefulness in the future had his life been spared. Mr. Hayward was devoted to his family, and will be remembered as a most amiable and interesting man. He became a member of the American Society of Civil Engineers September 5th, 1877.

WILLIAM HENRY GREENWOOD, Member A. S. C. E.

Died August 29th, 1880.

William Henry Greenwood was born in Dublin, New Hampshire March 27, 1832. His family removed to Marlborough, in the same state, in 1834, and he received his earlier education in the public schools of that place. As a boy he showed a great fondness for machinery and seemed to have inherited from his father considerable inventive genius. Quite early in life he determined to become a Civil Engineer and entered Norwich University in 1850, graduating in 1852. Directly after his graduation he was engaged upon the Central Military Tract Railroad, now the Chicago, Burlington and Quincy. He was afterwards connected with what was then known as the American Central Railroad and continued there until the commencement of the late war.

He enlisted on the 17th day of January, 1862, in the 51st regiment of Illinois Volunteers and was commissioned First Lieutenant, to date from his enlistment. He became Captain, May 9th, 1863, in the same regiment. Soon after the battle of Stone River Gen. Rosencranz selected Captain Greenwood to organize a topographical engineer service, and directed him to report, for better facilities for the observation of the country, to Gen. Stanley, at that time in command of the Cavalry of the Army of the Cumberland. As Lieutenant-Colonel and Inspector he continued with the 4th Corps of the Army of the Cumberland to the close of the war, and Gen Stanley states that no officer was present and participated in more battles, actions, affairs and skirmishes than Colonel Greenwood. He was entrusted with constant, difficult and delicate duties. He constructed a very large amount of field fortifications, and was especially known as one of the most indefatigable and enterprising officers of the corps. He was habitually careless as to his own safety. In 1865, still in the service of the government, he rebuilt the Gulf and San Antonia Railroad in Texas, which had been destroyed. After a short visit to his home he entered the service of the Kansas Pacific Railroad, of which he was appointed Chief Engineer in 1867, and while holding this position made surveys on the 32d and 35th parallels to the Pacific Coast. Under his direction some of the most rapid known railroad construction was accomplished. Upon completion of this road to Denver, in the summer of 1870, he resigned his position as Chief Engineer, and was soon afterwards appointed General Manager of the Denver and Rio Grande Railroad Company, and occupied that position until, the road was completed to Pueblo and Cañon City. Resigning this position he returned to the East in December, 1874, and spent all of the year 1875 in Vermont. He resided in Philadelphia during the year 1876, and in Vermont in 1877, engaged professionally only upon some minor

railroad operations. In May, 1878, he took charge of the construction of the railroad now operated by the Denver and Rio Grande Company through the Grand Cañon of the Arkansas and further west toward Leadville, to which work he devoted very remarkable energy and ability. During 1879 he was in charge of the construction of the Marion and MacPherson Railroad in Kansas. He left New York on the 19th day of May, 1880, for Mexico, and arrived in the City of Mexico on the last day of the month, where he directly took charge, as Chief Engineer, of the surveys for the Mexican National Railway under the control of Messrs. Sullivan and Palmer. Up to the end of August preliminary lines had been surveyed and location made between the City of Mexico and Toluca, distant about 44 miles, together with some extensions beyond that point.

On Sunday, August 29th, 1880, the camp of Colonel Greenwood and his party was near Toluca. He, with an assistant and a servant, started toward the City of Mexico, and had proceeded to within about 15 miles of that city when the assistant and the boy left the Colonel temporarily, but found upon following him that he had ridden quite a distance ahead. He was followed rapidly, but after crossing a deep ravine at a small mill at the top of a plateau on the Mexican side, his dead body was found lying in the trail with a bullet hole through the left hand which also passed entirely through the body. He was also wounded upon the right wrist and slightly upon the head. His horse and arms were missing, but his watch, money and some valuable papers were untouched. The murder of Colonel Greenwood excited intense indignation and grief in the City of Mexico. His funeral was very largely attended and he was buried at the American cemetery, in Mexico.

Colonel Greenwood leaves a widow who had been his constant companion, not only at his home in Vermont, but also in the frontier towns where so large a part of his engineering life had been spent. She went with him to Mexico and was there at the time of his death.

All the associates of Colonel Greenwood for many years past unite in speaking of him with a personal affection and a regard for his professional ability which could only be inspired by remarkable characteristics both of the man and the engineer. Removed at a comparative early age, and in the prime of life, and in active exercise of important engineering duties, he will be remembered by those who knew him as one of the finest examples of the life and service of the American Railroad Civil Engineer. The very activity and constancy of his professional work, kept him in the extreme advance and he was therefore, not personally, known to so many members of the profession and of the society as if more of his time had been spent in larger cities and among other engineers.

He became a member of the American Society of Civil Engineers on March 3d, 1880, and was deeply interested in its objects and progress.

CHARLES A. TASKER, Junior Member A. S. C. E.

DIED OCTOBER 4TH 1879.

Charles A. Tasker was a graduate of the English High School, Boston, Mass., and commenced the practice of Civil Engineering in 1869, at South Boston. In 1870, he was engaged upon the Quincy, Missouri and Pacific Railroad, and afterwards upon the Memphis and St. Louis Railroad. In 1871, he became Assistant Engineer on the Cairo and Fulton Railroad, of Arkansas, where he remained until 1874 when he became connected with the Cincinnati Southern Railway. He was afterwards engaged upon the extension of the Atchison, Topeka and Santa Fè Railroad in New Mexico, where he had charge of the construction of bridges, etc. During the year 1879 he was engaged in the construction of the New York and Woodhaven Railroad, on Long Island, near New York City, which position he held at the time of his death.

Mr. Tasker secured the sincerest regard and respect for his abilities from the gentlemen with whom he was connected during the construction of this latter work, and the editor regrets his inability to obtain more detailed information with respect to the life of this deceased member.

Mr. Tasker joined the American Society of Civil Engineers, November 4th, 1874.

ADDITIONS TO

LIBRARY AND MUSEUM.

From John W. Bacon, Danbury, Conn.:

Twenty-Eighth Annual Report of the Railroad Commissioners of the State of Connecticut.

Ninth Annual Report of the Railroad and Warehouse Commission of Illinois, year ending Nov. 30, 1879.

Third Annual Report of the Board of Railroad Commissioners of Iowa, for year ending June 30, 1880.

Report of the Railroad Commissioners of the State of Maine, for the year 1880.

Fifth and Sixth Annual Reports of the Railroad Commissioners of Missouri, for the years 1879 and 1880.

Seventh Annual Report of the Railroad Commissioners of Wisconsin. Madison. 1881.

From H. Stanley Goodwin, Bethlehem, Pa.:

Report of the President and Directors of the Atlantic and Gulf Railroad Company, for 1876 and 1877.

Annual Reports of the Baltimore and Ohio Railroad Company. Baltimore, 1856, 1858.

Annual Reports of the Galena and Chicago Union Railroad Company, for 1858, 1860, 1861, 1862.

Annual Reports of the Grand Rapids and Indiana Railroad Company, for 1868, 1869, 1870.

Proceedings of the Ninth Annual Meeting of the Delaware Railroad Company. Dover, Del. 1861.

Report of the New Jersey Railroad and Transportation Company. John P. Jackson. Newark, N. J. 1858.

Annual Report of the Kansas Pacific Railway Company. St. Louis. 1873.

Reports and Exhibits of the Mobile and Ohio Railroad Company. December 31, 1875.

An Exhibit of the Condition of Affairs of the Grand Rapids and Indiana Railroad Company. Fort Wayne, Ind. 1866.

The Union Pacific Railroad, Omaha to the Mountains. Chicago. 1868.

Report of the North Missouri Railroad. W. Milnor Roberts. Philadelphia. 1866.

Annual Report of the Michigan Southern and Northern Indiana Railroad Company. March 1, 1868.

Report of the Directors of the Chicago, Burlington and Quincy Railroad Company. Presented to the Stockholders at the Annual Meeting, June 20, 1862. Chicago.

Twenty-Fifth Annual Report of the Board of Directors of the North Pennsylvania Railroad Company. January 14, 1878. Philadelphia.

Report of the President and Directors of the Morris Canal and Banking Company. April, 1867. Jersey City.

Annual Report of the Board of Directors of the Lehigh Valley Railroad Company. Philadelphia, 1869, 1870, 1871, 1872, 1873, 1874, 1878, 1881.

By-Laws, Articles of Association, Manufacturing Law, etc., of the West Branch, Coal, Iron Ore, and Lumber Company. May 14, 1864.

Report of the Cleveland and Mahoning Railroad. January, 1861, 1863.

Annual Report of the Directors of the Boston and Worcester Railroad Corporation, for 1857, 1858, 1859.

Annual Report of the Louisville, Cincinnati and Lexington Railroads. June 30, 1867. Louisville, Ky.

Annual Report of the President and Directors of the Louisville and Frankfort R. R. Co. Sept. 4, 1866, Louisville, Ky.

Annual Report of the President and Directors of the Virginia Central Railroad Company. Nov. 28, 1867. Richmond.

From Institution of Civil Engineers, London.

Scarborough Harbor Improvement. John Hawkins.

The Paroy Reservoir. William Bell Dawson.

The Use of Cellular Caissons. Charles Andrews.

The Empress Bridge over the Sutlej. James Richard Bell.

Explosions of Firedamp. Prof. Haton de la Goupillière.

Portland Cement Compo and Concrete at the Garvel Dock Works, Greenock. Walter Robert Kinipple.

Dredging on the Lower Danube. Charles Henry Leopold Kühl.

The Protective Works for Preventing the Threatened Outbreak of the South Rangitata River, N. Z. John Henry Lowe.

Imperial Government Railways of Japan. The Osakayama Tunnel, Otzu, Lake Biwa. Thomas Manson Rymer-Jones.

The Flow of the River Thames. John Taylor.

Note on the Friction of Timber Piles in Clay. Arthur Cameron Hurtzig.

From Thomas H. Loomis, Culiacan, Mexico:

Erie Railway Accounts. The True and False. Fact *vs.* Fiction. President P. H. Watson's Oaths contrasted with his assertions. 1874.

New York, Lake Erie and Western R. R., Reports of the Directors. Sept. 39, 1879-1880.

Annual Meeting of the Stockholders and the 7th and 12th Annual Reports of the Directors of the Pittsburgh, Cincinnati and St. Louis R. R Co. March 16, 1875-1880.

Fifty-fourth Annual Report of the President and Directors of the Baltimore and Ohio R, R. Co., year ending Sept. 30, 1880.

Fifth Annual Report of the Kentucky Central R. R. Co. May 25, 1880.

Report of the President and Managers of the Phila. and Reading R. R. Co. Jan. 13. 1878,

Twenty-eighth Annual Report of the Directors of the Penna. R. R. Co. March 9, 1875.

Ninth Annual Report of the Commissioner of Railroads and Telegraphs of Ohio. June 30, 1875. Columbus.

Special Report of the Commissioner of Railroads and Telegraphs. Columbus. 1881.

Report of the Commission on Affairs of the Trustees of the Cincinnati Southern R. R. Jan. 14, 1879. Cincinnati.

From Edward P. North, New York:

The World's Navigation. The Problem of River Mouths. W. P. Stackpole. Bloomington, Ill. 1879.

Report of Commissioners for Testing the Chicago West-side Pumping Engines. (M. Lane, Chas. H. Haswell, Henry Warrington, Commissioners.) Chicago. 1877.

An Address delivered before the Alumni Association of the Lehigh University. E. B. Coxe. Philadelphia. 1878.

Annual Report of the Nassau Water Department. Brooklyn, 1872.

History of Steam Navigation between New York and Providence. Chas. H. Dow. New York, 1877.

Communication from the Landscape Architect and Civil and Topographical Engineer, in relation to the Proposed Plan for Laying Out the Central District of the Twenty-third and Twenty-fourth Wards, Department of Public Parks, lying east of Jerome Avenue and west of Third Avenue and Harlem Railroad. F. L. Olmsted. J. J. R. Croes. 1877.

I. Preliminary Report of the Landscape Architect and the Civil and Topographical Engineer upon the laying out of the Twenty-third and Twenty-fourth Wards.

II. Report of the Landscape Architect and the Civil and Topographical Engineer, accompanying a plan for laying out that part of the Twenty-fourth Ward lying west of Riverdale Road. F. L. Olmsted. J. J. R. Croes. 1876.

From F. Guilford Smith, Buffalo, N. Y.:

A Discussion of the General Principle Involved in the Construction and Action of the Isometrical Truss Bridge. Charles Macdonald. Philadelphia. 1867.

Discussion on Joints of Railways. From the Journal of the Franklin Institute for July, 1857.

McCallum's Inflexible Arched Truss Bridge, D. C. McCallum. New York. 1859.

The Philadelphia and Erie R. R. Co. *et al. vs.* The Catawissa R. R. Co. *et al.*, and Andrew Scott *vs.* The Atalantic and Great Western R'y Co. *et al.* In the Supreme Court of Pensylvannia, Eastern District. January Term, 1864. Arguments for Defendants.

Annual Report of the Commissioners on the Troy and Greenfield R. R. and Hoosac Tunnel. Boston. 1867.

Sur le percement du grand tunnel des Alpes. M. Conte.

Notes on Polytechnic or Scientific Schools in the United States. S. E. Warren. New York. 1866.

Agreement between the Atlantic and Great Western Railway Company and the Philadelphia and Reading Railroad Company. Philadelphia. 1866.

The Philadelphia and Erie Railroad Co. *et al. vs.* the Catawissa Railroad Co. and others. In the Supreme Court of Pennsylvania in and for the Eastern District. Affidavits for Defendants. January, 1866.

The Philadelphia & Erie R. R. Co. *et al. vs.* The Catawissa R R. Co. *et al.*, Andrew Scott *against* The Atlantic and Great Western R'y Co. *et al.* In the Supreme Court of Pennsylvania, Eastern District. January, 1866. Opinion of Court and Decree.

The Junction Railroad Company *vs.* The Pennsylvania Railroad Co. and J. Edgar Thomson. President of said Company. In the Supreme Court of Pennsylvania, Eastern District. In Equity. (2 copies.)

Act of Incorporation of the Mahony and Broad Mountain Railroad Company. Philadelphia. 1861.

Report of the Board of Managers of the Mine Hill and Schuylkill Haven Railroad Company. Philadelphia . 1861.

List of officers and Directors and Act of Incorporation of the Bethlehem Railroad Company. 1862.

Annual Report of the Pittsburgh, Titusville and Buffalo Railway Co. Philadelphia, 1880.

Report of the President and Managers of the Philadelphia and Reading Railroad Co. Philadelphia. 1855, 1862, 1863, 1864 (2 copies), 1866 and 1867.

A Problem in Practical Surveying : Demonstrated by means of Transversals. W. M. Gillespie. March, 1857.

Tracing of the West Branch Bridge, P. R. R, J. Dutton Steele, C. E.

Tracing of Peacock's Lock Bridge. J. Dutton Steele, C. E.

Tracings of Third Crossing Bridge. P. & R. R. R. J. Dutton Steele, C. E.

Tracings of Sanatoga Bridge. J. Dutton Steele, C. E.

Profiles of the Canals and Railroads for Transporting Anthracite Coal from the several Coal Fields to the City of New York. J. Dutton Steele. 1857.

From D. Van Nostrand, New York:

The Aneroid Barometer; its Construction and Use. Van Nostrand's Science Series. No. 35. New York. 1878.

Geographical Surveying; its Uses, Methods and Results. Frank de Yeaux Carpenter, C. E. Van Nostrand's Science Series. No. 37. New York. 1878.

Maximum Stresses in Framed Bridges. Prof. Wm. Cain, A. M. C. E. Van Nostrand's Science Series. No. 38. New York. 1878.

Voussoir Arches applied to Stone Bridges, Tunnels, Domes and Groined Arches. Wm. Cain, C. E. Van Nostrand's Science Series. No. 42. New York. 1879.

Turbine Wheels. Prof. W. P. Trowbridge. Van Nostrand's Science Series. No. 44. New York. 1879.

Linkages; the Different Forms and Uses of Articulated Links. J. D. C. De Roos. Van Nostrand's Science Series. No. 47. New York, 1879,

Theory of Solid and Braced Elastic Arches, Applied to Arched Bridges and Roofs in Iron, Wood, Concrete, or other Materials. Wm. Cain, C. E. Van Nostrand's Science Series. No. 48. New York. 1879.

Dwelling Houses: their Sanitary Construction and Arrangements. Prof. W. H, Corfield, M. A., M. D. Van Nostrand's Science Series. No. 50. New York. 1880.

Four Lectures on Electric Induction. F. E. H. Gordon, Royal Institution. New York. 1881.

Manual of Hydraulic Mining, for the use of the Practical Miner. S. F. Van Wagenen, E. M. New York. 1880.

Electric Lighting by Incandescence, and its Application to Interior Illumination. W. E. Sawyer. New York. 1881.

Sewers and Drains for Populous Districts with Rules and Formulæ for the Determinationsof their Dimensions under all Circumstances. J. W. Adams. New York. 1880.

A Guide to the Determination of Rocks, being an Introduction to Lithology. Edouard Jannettas. Translated from French by Geo. W. Plympton, C. E. A. M. New York. 1877.

Researches in Graphical Statics. Henry P. Eddy, C. E., PH. D. New York. 1878.

A Treatise on the Principles and Practice of Levelling. F. W. Simms. New York. 1876.

The Use of Steel. J. Barba and A. L. Holley. New York. 1875.

Earthwork Mensuration, on the Basis of the Prismoidal Formula. C. R. Howard. New York. 1874.

A Manual of Heating and Ventilation. F. Schumann. New York. 1877.

Skeleton Structures, of Steel and Iron Bridges. Olans Henrici. New York. 1867.

A Treatise on Accounts, in Connection with Ventilation. A. Saeltzer. New York. 1872.

A Practical Treatise on Roads, Streets and Pavements. Gen. Q. A. Gillmore. New York. 1876.

Weights and Measures According to the Decimal System. B. F. Craig. New York. 1876.

Engineers, Contractors and Surveyors' Pocket Table Book. J. M. Scribner. New York. 1878.

A Treatise on Engineering Construction. J. E. Shields. New York. 1877.

On the Construction of Iron Roofs. Francis Campin. New York. 1868.

A Treatise on the Method of Government Surveying. S. V. Clevenger. New York. 1877.

The Plane Table and its use in Topographical Surveying. From the Papers of the U. S. Coast Survey. New York. 1869.

American and European Railway Practice in the Economical Generation of Steam. A. L. Holley. New York and London. 1867.

The Naval Dry Docks of the United States. C. B. Stuart. New York and London. 1870.

On the Use of the Barometer on Surveys and Reconnaissances. New York and London. 1868.

Iron Truss Bridges for Railroads. Methods of Calculating Strains, with a Comparison of the most Prominent Truss Bridges, and New Formulas for Bridge Computations. Col. W. E. Merrill. New York. 1875.

Lives and Works of Civil and Military Engineers of America. C. B. Stuart. New York. 1871.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
DOANE, WALTER A.	Chief Engineer Meadville Railway, Meadville, Pa.	Sept. 7, 1881
HIDER, ARTHUR	Assistant U. S. Engineer, 2828 Washington Ave., St. Louis, Mo.	" "
JUDSON, WILLIAM P.	Assistant U. S. Engineer, Oswego, N. Y.	" "
MCKENZIE, THEODORE H.	Peck, Stow & Wilcox Co., Southington, Conn.	" "
MURDOCH, GILBERT	Chief Engineer Water Works, St. Johns, New Brunswick	" "

ASSOCIATE.

HENDRIE, JOHN S.	Engineer Detroit, Mackinaw and Marquette Railway, Marquette, Mich.	" "

CHANGES AND CORRECTIONS.

MEMBER.

FIELD, GEORGE S. ..... Central Bridge Co., Buffalo, N. Y.

JUNIORS.

HAYES, EDMUND ..... Central Bridge Co., Buffalo, N. Y.

PERKINS, CHARLES P. ..... Engineer Pittsburgh and Erie Division, Pennsylvania R. R., Williamsport, Pa.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—October, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

September 21st, 1881.—The Society met at 8 p. m., Vice-President Welch in the chair. A paper by D. McN. Stauffer, Member A. S. C. E., subject, Shaft Sinking under difficulties at Dorchester Bay Tunnel, Boston, Mass.; was read by the author and discussed.

October 5th, 1881.—The Society met at 8 p. m., William E. Worthen in the chair. Ballots were canvassed and the following candidates declared elected as members: Alfred Brittain, Montreal, Canada; Joseph R. Thomas, Brooklyn, N. Y.; John A. L. Waddell, Council Bluffs, Iowa.

The following proposed amendments to the Constitution were presented and read:

Proposed Amendments to Article XXIV.

After the words "Fellowship Fund" at the end of the first line, in-

sert the words, "Ten Thousand Dollars of which shall be," so as to read: "There shall be a fund called the Fellowship Fund, ten thousand dollars of which shall be devoted exclusively to the publication of the papers read before the Society," &c. &c.,

Also add at the close of the article, the words, "Fellows shall be elected in the same manner as Honorary Members."

The above amendment is proposed by the following named members of the Society: O. Chanute, Ashbel Welch, George S. Field, Walter Katté, Charles Paine, Alf. P. Boller, F. Collingwood, W. H. Paine, C. V. Smith, Jos. P. Davis.

Proposed Amendment to Article V.

Second line by striking out the word "five" and inserting the word "ten," so that it shall read "ten Directors."

The above amendment is proposed by the following named members of the Society: W. E. Worthen, A. F. Wrotnowski, Chas. H. Haswell, O. Chanute, Jos. P. Davis.

Proposed Amendment to Article XXXIII.

Strike out the word "October" in the third line and substitute therefore the word "November."

Also strike out the word "February" in the eighth line and substitute the word "March."

The above amendment is recommended for adoption by the Board of Direction, being consequent upon the change already made in the time of the Annual Meeting, and is formally proposed by the following named members of the Society: O. Chanute, W. H. Paine, C. V. Smith, Joseph P. Davis, John Bogart.

The following proposed amendment to the By-Laws was presented and read.

Section 24, third clause, strike out the word "October" and substitute the word "November."

The above amendment is recommended for adoption by the Board of Direction on account of the change already made in the time of the Annual Meeting, and is formally proposed by the following named members of the Society: O. Chanute, W. H. Paine, C. V. Smith, Jos. P. Davis, John Bogart.

The paper by D. McN. Stauffer, Member A. S. C. E., read at the previous meeting, subject, Shaft Sinking under difficulties at the Dorchester Bay Tunnel, Boston, Mass.; was discussed by Messrs. Bogart, Joseph P. Davis, Glaskin and Chanute.

The subject of the Point of Reference for Strains was introduced by Theodore Cooper, and discussed by Messrs. Chanute, Joseph P. Davis and W. H. Paine.

MEMOIRS OF DECEASED MEMBERS.

GEORGE THOMAS HALL, Member A. S. C. E.,

DIED JUNE 2D, 1881.

George Thomas Hall was born in Malta, Saratoga County, New York, April 6, 1845. He became an Associate Member of the American Society of Civil Engineers October, 2d, 1872, and a Member, September 2d, 1874.

At an early age he manifested a fondness for study; attended the Boy's Academy at Ballston Springs, and at the age of 17 taught a large school of advanced pupils. Two years later he graduated from the Normal College at Albany, and after remaining the following year, as a teacher, he entered the sophomore class of the Rensselaer Polytechnic Institute, at Troy, New York, from which he graduated in 1868, taking the degree of Civil Engineer. Here he had the reputation of an earnest and patient student, and his genial and companionable nature made him a great favorite with his fellow students, who honored him with their choice of class orator.

Soon after completing his professional education, which was accomplished only through the persevering effort of a determined will in overcoming many obstacles of a pecuniary sort, he began service as a transitman on the New York, New Haven and Willimantic Railroad under Gen. E. W. Serrel, Chief Engineer, taking high rank and performing satisfactory service in what was regarded as an unsually excellent corps on that line.

From there he went to Canada, holding a responsible position in the construction of 180 miles of the North Shore Railroad. Money failing, this new enterprise was abandoned, when he returned to the States and took a position as chief of corps on the West Shore Railroad under Gen. Stuart.

We next find him in New York City making the first surveys for the Gilbert Elevated Railway, upon which he was engaged for some time, until its further development was suspended.

NOTE,—Committee to prepare memoir; F C. Prindle and John Bogart, Members A. S. C. E. Special acknowledgement for assistance in the preparation of this memoir is made to Wm. F. Shunk, Esq., C. E.

He was soon after appointed State Division Engineer on the Champlain Canal enlargement, and located at Whitehall, New York, where he remained for three years. He performed the responsible duties and trusts connected with this important public work with marked fidelity and ability, and was particularly zealous and watchful in the State's interests.

While here he was elected Captain of the Separate Company of the State National Guard of Whitehall, and served with great acceptance in that capacity, proving himself a most intelligent and efficient as well as popular officer, who contributed much to the excellent discipline and drill of his command.

His company was called out during the railroad riots of that period, and his command was quartered a part of the time in Troy, where he rendered efficient service by the exercise of great tact in the dispersion of riotous mobs without the necessity of resorting to extreme measures. The excellent discipline and fine bearing of Captain Hall's command under these circumstances were noteworthy.

From Whitehall he returned to New York as Division Engineer of the Elevated Railway, which position he held until his death, June 2, 1881.

Just prior to his last sickness he was offered an important position in charge of the construction of public works under the Government, at a Southern navy yard, but which he declined, preferring to retain his connection with the Elevated Railway, in the study and construction of which he was so much interested, professionally, and with which he had been so long and closely identified.

All of the valuable service rendered by Captain Hall in the prosecution of this important work will never be generally known. He had charge of the foundation work on the Second Avenue line, as well as on Eighth and Ninth avenues, and his excellent paper read before the Society April 20, 1881, shows the method of his administration and his professional ability for the place.

In connection with this work, his Chief Engineer, Mr. William F. Shunk, furnishes this tribute to his skill in the performance of the many important matters entrusted to him: "He was systematic in the conduct of his work to an extraordinary degree. His record contains a perfect history of each foundation, and answered every question put, as to material, cost and time. The same as to tracklaying. But beyond his dutiful, skilful and diligent conduct of professional duties, Captain Hall did important service for the company that employed him, unknown to them and not likely ever to be known. I refer to the stilling of complaints and the amicable settlement of claims along the line of the road, a field of effort in which he could hardly be equalled, and where his generous nature, fine courtesy, and knowledge of mankind found ample room for exercise. It would

hardly be believed how incessant was the stream of such grievances, the greater portion of them never reaching the ears of the Board. Men with vaults invaded, light intercepted, sidewalks obstructed, water stopped, drains broken, or averred to be, butchers with meat tainted from the diggings, and innumerable other troubles, all charged to the railroad.

"And in addition to the multitude really aggrieved, or believing themselves so, there was an abundance of claimants put up to mischief by a class of curbstone lawyers who prowled the street for prey. Their business was, with perjury for a basis, to erect on it, under forms of law, a bill of damages in which they took a half interest. This bedlam rout dinned our ears without ceasing, and our diplomatic captain was constantly on the go. He quieted probably half of them by considerate attention, conciliatory remonstrance and prudent reasoning.

"Such of them as survived this witchery, he so ascertained the facts of, and located the witnesses, and reported the circumstances, that counsel usually found it easy to make a cheap compromise. These things distracted him from his proper work, and it was a department of service for which, in the nature of things, he could never have credit with the Directory. But he did it cheerfully and thoroughly."

Thus was he buisily occupied, until an alarming disease laid its hand upon him, which, for four weary months, made his life one of intense suffering. Slowly consuming the strength of this true, brave man, it could not daunt his cheerful and heroic spirit which was destined to enjoy the greater triumphs of calmly contemplating his approaching end, and patiently enduring his unassuageable sufferings with the unwavering faith and resignation of a Christian.

Of his personal worth and character many praises might be fitly sung; his eminent abilities of mind did not surpass the nobler qualities of heart and soul.

He was always a courteous gentleman, a warm and generous friend, and these noticeable characteristics combined with his winning manners, made one accept him, like any other fine make of nature, without questioning.

Peace to that great soul which we called by his name, not knowing all its greatness.

" He, being made perfect, in a short time fulfilled a long time. For though the righteous be prevented with death, yet shall he be in rest."

THE NORMAN MEDAL.

CODE OF RULES FOR ITS AWARD.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided. The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such Medal shall be of a cost equal to the annual interest received upon $1 000 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an Act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

IV.—The Board of Censors to award the Medal shall consist of three members of the Society, to be designated by the Board of Direction. The Secretary of the Society shall act as Secretary to the Board of Censors.

V.—The medal shall be awarded to such paper as the said Board shall judge to be worthy of special commendation for its merits as a contribution to Engineering Science, not merely relatively as compared with others presented during the same year, but as exhibiting the science, talent or industry displayed in the consideration of the subject treated of, and for the good which may be expected to result from the discussion and the inquiry.

VI.—In case no paper presented during the year shall be deemed of sufficient value to receive an award, the amount of the interest of the fund for that year shall be expended by the Board of Direction in the purchase of books, to be offered as a premium for the second best paper in the next year in which more than one paper of sufficient value may be presented.

VII.—The medal year shall terminate on the first day of August, and the award shall be announced at the Annual Meeting.

VIII.—The Treasurer of this Society shall cause the medal to be prepared and delivered to, or deposited to the order of, the successful competitor, within two months after the Annual Meeting at which the same shall have been awarded.

ADDITIONS TO

LIBRARY AND MUSEUM.

From T. B. Blackstone, Chicago :
Ninth to the Eighteenth (Inclusive) Annual Reports of the Chicago and Alton Railroad. From 1871 to 1880.

From D. W. C. Brown, Sandusky, Ohio :
Reports to the Stockholders of the Cincinnati, Sandusky and Cleveland Railroad. From 1872 to 1880, inclusive.

From John Burton, Milwaukee, Wis. :
Reports of the Directors of the Detroit, Grand Haven and Milwaukee Railway, with Statements of Accounts, etc., for the years 1869–1870 and 1874.
Reports of C. C. Trowbridge, Receiver of the Detroit and Milwaukee Railroad. From 1875 to 1878.
Report of the Directors of the Detroit, Grand Haven and Milwaukee Railway. Detroit. 1880.

From M. M. Greene, Columbus, Ohio :
Fifth to the Twelfth Annual Reports of the Columbus and Hocking Valley Railroad. From 1873 to 1880.
First to the Fourth Annual Reports of the Columbus and Toledo Railroad. From 1877 to 1880.

From H. Keep, Chicago :
Reports of the Chicago and North Western Railroad for 1869, 1870 and 1874 to 1880.

From H. B. Ledyard, Detroit :
Annual Reports of the Directors of the Michigan Central Railroad. June, 1847, 1848, 1858, 1863, 1864. 1865, and year ending December 31. 1880. Detroit and Boston, and Circular of the Treasurer, December 26, 1855.

From Charles Paine, Cleveland :
Annual Reports of J. H. Devereux, Receiver of the Atlantic and Great Western Railroad for the years 1872, 1875 and 1876 to 1880. Cleveland.
Lake Shore and Michigan Southern Railroad. Local Freight Classification to take effect April 4, 1881. Cleveland. 1881.
Eighth Annual Report of the Railroad Commissioners of Michigan for the year ending December 31, 1879. Lansing. 1880.
New York, Pennsylvania and Ohio Railroad. Proceedings of the Meeting of Officers held at Cleveland, Ohio, March 23, 1881. Jamestown. 1881.
First Annual Report of the New York, Pennsylvania and Ohio Railroad for the year 1880.
Eleventh, Twelfth and Thirteenth Annual Reports of the Commissioner of Railroads and Telegraphs for the years ending June 30, 1877, 1878, 1879. Columbus, Ohio,
The St. Louis, Alton and Terre Haute Railroad *vs.* The Indianapolis and St. Louis, The Lake Shore and Michigan Southern, The Cleveland, Columbus, Cincinnati and Indianapolis, The Pittsburgh, Fort Wayne and Chicago, The Indianapolis, Cincinnati and Lafayette, and the Pennsylvania Railroad Companies, and the Pennsylvania Company. Case No. 6,257, Circuit Court, U. S. Indiana.

From C. E Perkins, Chicago :
Twenty-third to the Twenty-seventh Annual Reports of the Directors of the Chicago, Burlington and Quincy Railroad. From 1876 to 1880.
Reports of the Directors of the C. B. & Q. R.R. presented at the Annual Meetings, June 21, 1861, February 24, 1875, and February 23, 1876.

From H. Riddle, Chicago :
Annual Reports of the Chicago, Rock Island and Pacific Railroad for the years 1869, 1871, 1872 and 1874 to 1880.

From H. C. Potter, East Saginaw, Mich.:
Annual Reports of the Flint and Pere Marquette Railroad for the years 1867, 1869 to 1872 to 1880.
O. Prescott, W. W Craps, A. G. Pierce and P. V. Rogers, Trustees of the Flint and Pere Marquette Railroad, Complainants, *vs.* The Flint and Marquette Railroad, Defendants.
Report of H. C. Potter, Receiver. January 12, 1881.

From E. B. Thomas Cleveland :
Annual Reports of the Directors of the Cleveland, Columbus and Ohio Railroad for the years 1860, 1862, 1868, 1869 to 1873 and 1874 to 1880,

From J. F. Tucker, Chicago :
Report and Accounts of the Illinois Central Railroad for the years 1868 to 1871 to 1880.

From L. Williams, Cincinnati :
Fourth, Fifth, Sixth and Twenty-second to Thirty-third Annual Reports of the Cincinnati, Hamilton and Dayton Railroad for the years 1854, 1855, 1856 and 1869 to 1880.

From Wm. E. Worthen, New York :
Reports to the Lords of the Committee of Privy Council for Trade upon the Accidents which occurred on Railways during the years 1856, 1857 (2 copies), 1858. Capt. D. Galton, R. E. London.
Reports of the Number of Accidents and the injuries of Life and Limb which have occurred on Railways of Great Britain from July 1 to December 31, 1855. London. 1856.
Reports of the Inspecting Officers of the Railway Department upon Certain Accidents which have occurred on Railways of Great Britain during the months of August, September, October, November and December, 1855, 1857 and 1858.
Reports of the Inspecting Officers of Railway Department upon Certain Accidents which have occurred on Railways of Great Britain during the months of January, February, March and April. Part II., 1857. Parts I., II., III. and IV., 1858 ; and Parts I., II. and IV., 1859,

Reports of the Inspecting Officers of the Railway Department of Great Britain upon Four Accidents which occurred on the South-Eastern Railway, 1855. London. 1856.
Return of the Number and Nature of the Accidents and Injuries of Life and Limb which have occurred on the Railways of Great Britain from July 1 to December 31, 1856. London. 1857.
Report of the Commissioners of Railways of Great Britain for the year 1850. London. 1851.
First, Second, Third, Fourth and Fifth Reports of the Select Committee on Railways and Canal Bills, together with Minutes and Evidence and Appendix. December 16, 1852. February 28, 1853. March 18, 1853. April 8. 1853. July 8, 1853. London.
Returns showing the Number of Passengers conveyed on all the Railways of Great Britain, distinguished in different classes, and the Receipts from each Class of Passengers. and from Goods, Etc., Etc., during the half years ending December 31, 1856, 1857 and 1858.
Testimony taken before the Committee on Railroads in relation to the Accident which occurred on the Hudson River Railroad, at New Hamburgh, on Monday, February 6, 1871. Albany. 1871.
Report upon a Plan of Construction of several of the Principal Railroads in the Northern and Middle States, and upon a Railway Structure for a new track on the Baltimore and Ohio Railroad. J. Knight, Chief-Engineer, and Benj. H. Latrobe, Engineer of Location and Construction. Baltimore. 1838.
Report to the Stockholders of the Boston, Hartford and Erie Railroad. September 25, 1864. Hartford. 1864.
Prospectus of the New York, Housatonic and Northern Railway. New York. 1864.
Report of the Commissioners upon the Troy and Greenfield Railroad and Hoosac Tunnel. Boston. 1869.
Annual Report of the Commissioners on the Troy and Greenfield Railroad and Hoosac Tunnel. Boston. 1867.
Report of Benj H. Latrobe, Consulting Engineer, on the Troy and Greenfield Railroad and Hoosac Tunnel. Boston. 1869.
The Charters on the Leavenworth, Pawnee and Western Railway Company, and all Laws of Kansas affecting its Duties, Powers and Liabilities. New York. 1862.
Report of the Board of Directors to the Stockholders of the New York and New Haven Railroad. May 13, 1858. New York. 1858.
Report of the Executive Committee having in charge the Surveys relating to the Peekskill and Carmel Railway. Peekskill. 1860.
A Reply to the Speech of Mr. Charles Francis Adams, Jr., before the Joint Standing Committee on Railroads of the Massachusetts Legislature. R. S. Spofford. Boston. 1873.
Report on the South Pennsylvania Railroad; also, its Charter and Supplements. Harrisburgh. 1869.
Report of the Joint Standing Committee on the Troy and Greenfield Railroad and Hoosac Tunnel for the year 1858.
Grant of Lands by the United States to the State of Missouri for Railroad Purposes, and Acts passed by the Legislature affecting the Southwest Branch of the Pacific Railroad. St. Louis. 1859.
Pelteler Portable Railroad Company. New York. 1871.
Lands for Sale by the Pacific Railroad Company. St. Louis. 1859.
Metropolitan Railway Company. Half-Yearly Report. Aug. 9, 1871.

REPORT OF THE FINANCE COMMITTEE

ON THE SUBJECT OF

COMPOUNDING ANNUAL DUES BY ONE PAYMENT.

To the Board of Direction of the

American Society of Civil Engineers:

GENTLEMEN,—The Finance Committee, to which was referred the subject of a proper sum for compounding the dues of members for life, by one payment, have carefully considered the subject, and herewith present the results of their investigations and the conclusions arrived at.

The most laborious portion of these investigations has been done in a very thorough manner by Mr. Bogart, the secretary of this Society, who has compiled from the records, statements having a direct bearing

upon this subject, which are of so much practical importance and rea-interest to the Board, that we incorporate them entire, adopting them with his conclusions as a part of our report.

Mr. Bogart's report is as follows :

New York, May 9, 1881.

Col. Wm. H. Paine, *Director, A. S. C. E.,*
Chairman of Finance Committee:

Dear Sir,—In connection with the resolution of the Board referred to the Finance Committee, as to the sum proper for compounding dues by one payment, for life, I venture to submit to the Committee some points I have gathered while considering the subject.

There has recently been submitted an amendment to the Constitution which proposes the payment of $300.00 by a resident member, and $150.00 by a non-resident member, as a compounding sum for life, with a provision that a non-resident becoming a resident, shall pay the remainder of the composition, viz., $150.00, or the usual annual subscription during the time of his residence.

The annual dues of the Society now are :

For members, resident.	$25 00	Non-resident	$15 00
For associates, "	15 00	"	10 00
For juniors, "	15 00	"	10 00

The admission fees are : For members, $30 ; Associates, $20 ; Juniors, $20.

The annual dues of the Institution of Civil Engineers in England are :

For members, resident,	4 guineas.	Non-resident	3 guineas.
For associates, "	3 "	"	2½ "
For students, "	2 "	"	1½ "

The admission fee is : For members and associates, 10 guineas.

The Institution of Civil Engineers permits "any member or associate, whose subscription is not in arrears, if resident in the United Kingdom, to compound for future annual subscriptions by the payment of fifty guineas. Any member or associate residing abroad, may compound by the payment of twenty-five guineas, but should he come to reside in the United Kingdom, he shall pay the remainder of the composition,

viz., twenty-five guineas, or the usual annual subscription during such residence. All such compositions shall be invested, and the interest alone shall be appropriated to the current expenditure of the Institution, except by special direction of the council, on the report and recommendation of the Finance Committee.

The terms, resident and non-resident, are applied as regards dues, in the English Society, respectively to persons residing within ten miles of the General Post Office, in London, and to persons residing beyond those limits.

But the provision for compounding dues gives the low rate only to persons residing outside the United Kingdom; all persons residing within the United Kingdom being compelled to pay the full compounding sum of fifty guineas.

Residency, as arranged by the law of the American Society, applies to all who reside within fifty miles of the New York Post Office.

By the last report of the Board of Direction, November, 1880, the membership in the American Society was:

Resident members	114	Non-resident members	359
" Associates	6	" Associates	14
" Juniors	6	" Juniors	42
Total paying resident	126	Non-resident	415
Resident honorary members	3	Non-resident hon. members	9

Resident members	129
Non-resident members	424
Fellows, who are not members	55
Corresponding members	3
Total	611

Suppose the plan suggested be adopted, and also suppose it generally followed by members, the result would be (omitting from the calculation Associates and Juniors and also Honorary and Corresponding members who pay no dues):

114 Resident Members, paying $300 each, would give	$34 200
359 Non-resident Members, paying $150 each, would give	53 850
Or a capitalized fund of	$88 050

The highest rate of interest safe to assume as receivable on trust funds is probably 5 per cent., which, on $88 050 would give, per annum, $4 402 50.

The amount now received from the same number of members is :

114 Resident Members, at $25 each	$2 850 00
359 Non-resident Members, at $15 each	5 385 00
Total per annum	$8 235 00
If funded as above, per annum	4 402 50
Or an annual present decrease in the income of the society of	$3 832 50

or about 46½ per cent. decrease from the present income received from these members. In other words, we would only receive, per annum, about 53½ per cent. of the amount now received from these members.

Even at 6 per cent. the income would only be $88 050 at 6 per cent	$5 283 00
Present income from same members	8 235 00
Annual deficiency at 6 per cent	$2 952 00

The total income of the society from every source was last year $12 473 04, as follows :

Entrance Fees	$1 850 00
Current Dues	6 366 41
Past Dues	835 00
Advance Dues	2 246 13
Interest on funds	785 20
Other sources	390 30
Total income	$12 473 04

The loss, with the compounding payments capitalized at 5 per cent. would be a little over 30 per cent. on the total present annual income of the society.

On the other hand, it may be considered that the payments made for compounding dues become permanent investments for the society, and that if the society is able to stand the annual loss for a period of years,

it will eventually be the the gainer from the fact that as members die or resign, their dues cease, while the interest on a capitalized sum remains perpetual.

The annual *loss* of members for a series of years has been :

Year ending	Total Membership.	Loss from all causes.	Percentage of Loss.
Nov., 1873	414	6	1.45
" 1874	445	22 *	4.94
" 1875	492	8	1.63
" 1876	552	5	0.91
" 1877	574	15 †	2.61
" 1878	593	7	1.18
" 1879	601	20 †	3.32
" 1880	611	58 ‡	9.49
Averages	535.25	17.625	3.29

The average annual loss of members has thus been about 3.29 per cent. from all causes, but the dropping of 45 members for non-payment of dues in one year (1880) was unusual ; without that loss of 45 members the percentage of loss would average only 2.24 per cent. per annum. Probably 3 per cent. per annum will fairly cover the loss, as far as experience shows in the past.

On the general basis of the present paying membership of the Society and on the amount which would be realized if the plan of compounding were adopted there would be, as stated above, a sum of, say, $4 400 per annum, realized from the capitalized fund, at 5 per cent.

These same members now pay, say, $8 000 per annum. This sum would be reduced 3 per cent. per annum by loss of members through death or resignation.

On this basis, and without reference to new membership, the annual income from these members for a series of years would be :

* Fourteen dropped for non-payment of dues.
† Ten deceased.
‡ Forty-five dropped for non-payment of dues.

Successive Years.	Income under present system of Dues, reduced 3 per cent. each year.	Income if dues are compounded, and the amount capitalized at 5 per cent.	Income less under compounding plan than under present system.	Income more under compounding plan than under present system.
Present Year.	$8 000 00	Nothing	$8 000 00	
1	7 760 00	$4 400 00	3 360 00	
2	7 527 20	4 400 00	3 127 20	
3	7 301 38	4 400 00	2 901 38	
4	7 082 34	4 400 00	2 682 34	
5	6 869 87	4 400 00	2 469 87	
6	6 663 78	4 400 00	2 263 78	
7	6 463 87	4 400 00	2 063 87	
8	6 269 95	4 400 00	1 869 95	
9	6 081 85	4 400 00	1 681 85	
10	5 899 39	4 400 00	1 499 39	
11	5 722 41	4 400 00	1 322 41	
12	5 550 74	4 400 00	1 150 74	
13	5 384 22	4 400 00	984 22	
14	5 222 69	4 400 00	822 69	
15	5 066 01	4 400 00	666 01	
16	4 914 03	4 400 00	514 03	
17	4 766 61	4 400 00	366 61	
18	4 623 61	4 400 00	223 61	
19	4 484 90	4 400 00	84 90	
20	4 350 35	4 400 00		$49 65
21	4 219 84	4 400 00		180 16
22	4 093 24	4 400 00		306 76
23	3 970 44	4 400 00		429 56
24	3 851 33	4 400 00		548 67
25	3 735 79	4 400 00		664 21
26	3 623 72	4 400 00		776 28

It will be seen that, on the basis assumed, the income would be less than from the present system for more than 19 years; after that it would become greater.

The capitalization of the fund at 5 per cent. has been assumed, because it would not probably be possible to obtain more than that on the par value of the fund. No expenses for Trusteeship, &c., have been assumed.

If the above considerations are fairly correct, it would seem to follow :—

1. That the proposed measure of compounding at $150 and $300 would decrease the current income to an extent we cannot now afford.

2. That if desirable to compound dues, and at the same time not reduce the current income, higher rates must be assumed for compounding.

3. That if the present funds of the Society were anything like those of the English Institution, a measure of this kind might well be adopted, as we could then afford a present loss of income for an ultimate increase.

NOTE.—The invested funds of the English Institution are :

Institution investments	£31,000
Trust funds	45,700
Total	£76,700
Or, say	$383,500
The annual income of the English Institution is about	£14,200
Or, say	$71,000

Very respectfully,

JOHN BOGART,
Secretary.

An examination of the statements presented by Mr. Bogart shows that if the compounding of dues at the rate of $300 for resident members and $150 for non-resident members was adopted and generally followed, the effect upon our revenues would be disastrous, as it would cut off our entire revenue from this source the first year, and diminish it nearly 50 per cent. the second year; not reaching its full amount until 19 years hence.

It is not probable that the practice of compounding dues would be

immediately and generally followed. But if this plan should meet with favor, and any considerable number of members should compound their dues, there would be as large a percentage of falling off of proceeds from dues as there would be percentage of members compounding, as all such members would cease to pay dues, and the interest from the sums paid in would not be available during the first year.

The second year there would be a loss of nearly fifty per cent. of the dues of those who had compounded the year before, and, added thereto, would be a total loss of all the dues of members compounding that year.

And each succeeding year the lessening of the dues would go on until a maximum of decrease would be reached, an uncertain number of years hence, when the revenue would gradually increase again, if the Society survived the experiment.

We further notice that if non-resident members should compound in larger proportionate numbers than resident members, there would be a still greater falling off of income.

The proposed compounding rates being less in proportion for non-residents than residents, as compared with the dues now paid by each, would tend to encourage a disproportionate number of non-residents to compound, and this disproportion would tend to produce the result mentioned.

We would also call attention to the probability that the class of members most likely to compound their dues would be those best able to pay their dues promptly, and who have reasonable prospects of living long enough to make the sum paid for compounding a good investment; and, if through such an experiment as this proposed, or from any other cause the dues should require to be increased, this extra burden would fall upon others, leaving this class exempt.

With these facts before us, and in the present state of our finances, when our expenses so nearly correspond with our income, we cannot recommend any basis for compounding dues which shall tend to lessen our present annual income.

The plan of compounding the dues of members on the basis proposed would tend to seriously lessen our annual income. And the more generally this plan came into practice, the greater would be our financial embarrassment.

The only amounts that, under the present circumstances, would be

safe to adopt would be so large as to appear unreasonable, and tend to discourage members from compounding.

While we look with favor upon the plan of compounding dues as having for its object the permanent and best interests of this Society, and which, if in successful operation, would in time accomplish all that might be expected of it, yet we fear that its introduction at the present time might so seriously embarrass the Society financially as to jeopardize those important interests which this plan was especially designed to subserve.

We therefore recommend that this proposed amendment to the Constitution be not adopted.

Respectfully submitted,

W. H. PAINE,
JOS. P. DAVIS.
C. V. SMITH,
Committee on Finance.

HOUSE OF THE SOCIETY, October 12, 1881.

LIST OF MEMBERS.

ADDITIONS.

MEMBERS.

		Date of Election.
BLACKWELL, CHARLES	Engineer Midland and Grand Junction Railways, Peterborough, Canada	Sept. 7, 1881
ENGLE, ROBERT L.	Engineer Rio Grande Ex. Co., Gunnison, Col.	" "
GOAD, CHARLES E.	102 St. Francis Xavier Street, Montreal, Canada	" "
KEITH, GEORGE T	Civil Engineer, Olean, N. Y.	May 4, 1881
PARENT, E. H.	Superintending Engineer Beauharnois, Lachine and Chambly Canals, Montreal, Canada	Sept. 7, 1881
SKILTON, GEORGE S	Assistant Chief Engineer Mexican Central Railway, City of Mexico, Mexico	" "
THOMAS, JOSEPH R.	Engineer Williamsburg Gas Co., Brooklyn, N. Y.	Oct. 5, 1881
WADDELL, JOHN A. L.	Engineer Raymond and Campbell Bridge Co., Council Bluffs, Ia.,	" "

CHANGES AND CORRECTIONS.

MEMBER.

BILLIN, CHARLES E.....Illiana, Edgar Co., Ill.
BLAND, JOHN C.....259 South 4th Street, Philadelphia, Pa.
BONTECOU, D.....P. O. Box L., Kansas City, Mo.
CHITTENDEN, S. H.....Corcoran Building, Room 69, Washington, D. C.
CUNNINGHAM, D. W.....Stillwater, Minn.
CUNNINGHAM, J. H.....50 Queen Street, Edinburgh, Scotland.
DOANE, WALTER A.....Principal Assistant Engineer Rome, Watertown and Ogdensburgh R. R., Oswego, N. Y.
FRAZIER, JAMES L..... Louisville, New Albany and St. Louis R. R., Louisville, Ky.
FULLER, SIDNEY T.....Chief Engineer Texas Mexican R. R., Galveston, Texas.
JOHN, IRVIN.....20 Nassau Street, Room 57, New York City, N. Y.
KINSLEY, THOMAS P.....Le Roy, Genesee Co., N. Y.
MACNAUGHTON, JAMES...Assistant Engineer North River Construction Co., Albany, N. Y.
MONROE, J. ALBERT.....Div. Engineer N. Y., W. S. & B. R. R., Rondout, N. Y.
NEWMAN, ROBERT M.....Engineer Jamestown Branch, Jamestown, Dakota.
ROBINSON, A. A.. .....Chief Engineer A. T. & S. F. R. R., Topeka, Kansas.
SCOWDEN, T. R.....1220 Lexington Avenue, Cleveland, Ohio.
SEARS, ALFRED F.....Assistant General Manager Mexican Central R. R., City of Mexico, Mexico.
SHINN, WILLIAM P.....Vice-President N. Y. Steam Co., 16 Cortlandt Street, New York City, N. Y.
SICKELS, T. E.....Consulting Engineer Union Pacific R. R., 197 Broadway, New York City, N. Y.
SMITH, ISAAC W.....Chief Engineer Oregon Pacific R. R., Corvallis, Oregon.
STAUFFER, D. MCN.....Philadelphia Bridge Works, 259 South 4th Street, Philadelphia, Pa.
STEPHENS, CLINTON F....Chief Engineer Texas and St. Louis R. R., Waco, Texas.
SWAN, CHARLES H.....25 Wabon Street, Boston Highlands, Boston, Mass.
SWEET, CHARLES A.....Assistant Engineer Mexican Central R. R., Leon, Mexico.
SWEET, E., JR.....16 Exchange Place, New York City, N. Y.
VAN BUREN, JOHN D., JR..Newburgh, N. Y.
VAUGHAN, F. W.....Consulting Engineer, Henderson Bridge Co., Louisville, Ky.
WAITE, C. C..... ....Assistant to President N. Y., L. E. and W. R. R., 21 Cortlandt Street, New York City, N. Y.
WALKER, JOHN S.....Huntsville, Ala.
WELLINGTON, ARTHUR M..Principal Assistant Engineer Mexican National R. R., Cadena No. 11, City of Mexico, Mexico.

JUNIORS.

ALLEN, JAMES P.....6 Glebe Street, Charleston, S. C.
EMONTS, W. A. G.....Langhorne, Bucks Co., Pa.

HORTON, SANDFORD.....Assistant Engineer Tehuantepec I. O. R. R., Jaltipan, Mexico.

STAHLBERG, A. J.....O. and C. R. R., Roseburg, Oregon.

ASSOCIATE.

WHEATON, EDWARD.....Care Wm. Frazier & Co., 64 Equitable Building, Boston, Mass.

DEATH.

CARTWRIGHT, HENRY.....Elected Member September 6, 1876. Died July 30, 1881

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—November, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

October 19th, 1881.—The Society met at 8 p. m., Past President E. S. Chesbrough in the chair.

The paper upon Experiments on Phœnix Columns, by Messrs. T. C. Clarke, John Griffen, A. Bonzano and David Reeves (Clarke, Reeves & Co.), which had been presented at the Convention at Montreal, June 18th, 1881, was discussed by Messrs. Charles E. Emery, D. V. Wood, Theodore Cooper, Thomas C. Clarke, and, through the Secretary, by G. Bouscaren.

November 2d, 1881.—The Society met at 8 p. m., Vice-President Welch in the chair.

A communication was presented from the Engineers' Club of Rio de Janeiro, Brazil, expressing sympathy for the death of Past President W. Milnor Roberts. Accompanying the communication was an album of photographs of the Dom Pedro Segundo Railway, the last road

traveled by Col. Roberts. The following named members were appointed a Committee to prepare an answer to the communication : Past President E. S. Chesbrough, Vice-President Ashbel Welch, and Secretary John Bogart.

Discussions upon the paper by Messrs. Clarke, Reeves & Co., subject, Experiments on Phœnix Columns, were presented, through the Secretary, from Messrs. William H. Burr, Theodore Cooper, C. L. Gates, Mansfield Merriman, C. L. Strobel, D. J. Whittemore and A. S. C. Wurtele.

November 16th, 1881.—The Society met at 8 p. m., Charles Macdonald in the chair.

The death of Henry Cartwright, Member of the Society, was announced and the appointment of a Committee authorized to prepare a memoir for publication.

The subjects discussed were : Protection against Slips in Clay Slopes by burning the clay in position at the foot of the slopes ; also the Lateral Thrust of Earthwork ; also apparatus for Supplying Steam, Heat and Power to Districts in Cities.

OF THE BOARD OF DIRECTION.

October 4th, 1881. — The Board determined to recommend the adoption of amendment to Article XXIII of the Constitution and to Section 24 of the By-Laws, as printed in Proceedings for October, 1881. The following resolution was adopted : that whereas, the beginning of the Society fiscal year has been changed from the first Wednesday in November to the first day of January, there will be due on November 2d, for the two months, November and December, 1881, two-twelfths of the regular annual dues, and the Secretary is directed to forthwith issue bills for these two months, with this explanatory note.

The censors for awarding the Norman medal were, under the rule, designated, namely, Messrs. Thomas C. Keefer, T. E. Sickels and Henry Flad.

The Secretary was instructed to prepare and issue a circular soliciting additional subscriptions to the Building Fund. The Secretary was instructed also to issue a circular soliciting additional contributions to the Library.

October 12th, 1881.—Applications were considered. The Committee on Finance made a report on the subject of Compounding Dues of Members by one payment for life.

November 2d, 1881.—Financial business was transacted and the investment of a portion of the Fellowship Fund in United States Bonds was ordered. The report of the Finance Committee on Compounding Dues was ordered printed. Appropriations were made.

THE NORMAN MEDAL.

CODE OF RULES FOR ITS AWARD.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided. The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such Medal shall be of a cost equal to the annual interest received upon $1 000 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an Act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

IV.—The Board of Censors to award the Medal shall consist of three members of the Society, to be designated by the Board of Direction. The Secretary of the Society shall act as Secretary to the Board of Censors.

V.—The medal shall be awarded to such paper as the said Board shall judge to be worthy of special commendation for its merits as a contribution to Engineering Science, not merely relatively as compared with others presented during the same year, but as exhibiting the science, talent or industry displayed in the consideration of the subject treated of, and for the good which may be expected to result from the discussion and the inquiry.

VI.—In case no paper presented during the year shall be deemed of sufficient value to receive an award, the amount of the interest of the fund for that year shall be expended by the Board of Direction in the purchase of books, to be offered as a premium for the second best paper in the next year in which more than one paper of sufficient value may be presented.

VII.—The medal year shall terminate on the first day of August, and the award shall be announced at the Annual Meeting.

VIII.—The Treasurer of this Society shall cause the medal to be prepared and delivered to, or deposited to the order of, the successful competitor, within two months after the Annual Meeting at which the same shall have been awarded.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Prof. R. H. Thurston, Hoboken, N. J.:

Proceedings of the Fifteenth Annual Meeting and List of Members of the New England Cotton Manufacturers Association. Boston. 1880.

Contract and Specifications for Road and Pipe Trench of the Fall River Water Works,

Improvement in Metals for Car Wheels. Hamilton Steel Wheel Co. Philadelphia.

Constitution and By-Laws of the New York Society of Practical Engineers. New York. 1870.

Report of E. L. Viele, Chief Engineer of the Arcade Under Ground Railway. New York.

Report of Observations on Railways made in 1874 and 1875. By Direction of the Government of Victoria. Melbourne. 1876.

A Practical Description of Herron's Patent Trellis Railway Structure. James Herron. Philadelphia. 1841.

A Description of Improvement in the Construction of Bridges. Ithiel Town. New York. 1839.

The Reading Railroad: Its Advantages for Cheap Transportation of Coal. Philadelphia. 1839.

Iron Piers for Deep Water. S. R. Dickson, C. E. New Haven. 1872.

Description of Sandberg's Standard Rail Sections.

Contract for Rails and Fastenings. Sandberg's Form of Specification.

Light Railways in Sweden. C. P. Sandberg. C. E. 1870.

Railways in Sweden: Their cost, gauge and speed. C. P. Sandberg. 1873.

Annual Report of the Hartford Steam Boiler Inspection and Insurance Co. Hartford. 1873, 1875, 1877. and 1878.

Civil Engineers Club of the North West. Deep Pile Driving in Wisconsin. C. W. Durham. 1875.

Leveeing on the Mississippi River. E. L, Corthell. 1874.

Improvement of the Mouth of the Mississippi River. James B. Eads. 1874.

Improvement in Electric Railway Signals, J. M. Goodwin. Cleveland. 1873.

An Act to Incorporate the New Jersey Railroad and Transportation Co. Newark. 1832.

Report on the Mississippi Jetties. Capt. J. B. Eads, 1876.

Annual Report of the Department of Docks of the City of New York. 1878.

Annual Report of the Chief Engineer of the Board of Public Works of Jersey City, N. J. 1877.

Progress of the Physical Department of the Mass, Institute of Technology, from 1867 to 1877. E. C Pickering. Boston. 1877.

Annual Catalogue with Minutes of the Ninth Annual Meeting of the Stockholders of the Swarthmore College. Swarthmore. Pa. 1873.

Letter of Sir Charles A. Hartley, on Jetties at the Passes of the Mississippi. Washington, D. C. 1875.

Report of Hearing before the Commissioners on Apportionment between Boston and Cambridge, of the Expense of Maintaining the West Boston and Canal Bridges. Cambridge. 1870.

Survey of Harbor and Mouth of Connecticut River. 1838.

The Jurisprudence of Surveys; A Paper read before the Civil Engineers Club of the North West. S. S. Greeley. 1873.

The Importance of Boulevards as a Means of Checking Conflagrations. H. S. Cleveland. 1874.

Mouth of the Mississippi. Canal and Jetties Compared.

Fifth and Sixth Report upon Improvement of the South Pass. Gen. C. B. Comstock.

Fourth, Fifth, Seventh, Eighth Annual Reports of the Board of Railroad Commissioners of Massachusetts.

Second Report of the New York and Erie Railroad Company. New York. 1841.

Bridging the Hudson at Poughkeepsie.

First Report of the Superintendent of Water Works of Newport, Ky. Newport. 1874.

Letter of the Mississippi Bar Pilots on Fort St. Phillips and South West Pass. Pilot Town, La. 1874.

Official Report on the Apparatus for Burning Liquid Fuel in Marine and Locomotive Boilers. A. C. Stiners. Boston. 1868.

A Protest from Gen. C. K. Graham against the needless expenditures of public money for the alleged necessary strengthening of the "Béton en Masse" Walls on the North River Front. New York. 1876.

Report of the Commissioners named by the Legislature of New Jersey Incorporating the Somerville and Easton Railroad. Elizabethtown. 1847.

Proposals for Cast Iron Water Pipes and Special Castings for the Fall River Water Works.

Contract and Specifications for Streets and Roads of the City of Fall River.

Contract and Specifications for Trenching and Back-filling for Water Pipes for the Fall River Water Works.

Annual Report of the Denver and Rio Grande Railway. Philadelphia. 1873.

Improvement of the Mississippi River at or near the Falls of St. Anthony. Gen. G. K. Warren.

An Account of some of the Bridges over the Charles River. Cambridge. 1858.

Annual Reports of the Lake Shore and Michigan Southern Railway Co. Cleveland. 1874 and 1877.

Memoir of the Delaware and Raritan Canal and Camden and Amboy Railroad. 1834.

Survey of Sandusky Harbor. 1838.

Annual Report of the Louisville and Nashville Railroad. Louisville, 1875.

Annual Report of the American Railway Master Mechanics Association. Cincinnati. 1876.

A Memorial on Behalf of the Removal of Muscle Shoals Obstruction of the Tennessee River. Chattanooga. 1878.

Annual Report of the Boston Water Works. Boston. 1879.
An Address on the Railways and Telegraphs of the Nineteenth Century. S. B. Ruggles. New York. 1866.
A Statement of the Relations of Railroads to the Public. F. B. Thurber. New York. 1878.
A New Lantern Galvanometer. A. M. Nayer.
Survey of the Harbor of Lynn, Massachusetts. 1838.
Annual Report upon the Surveys of Northern and North Western Lakes. Gen. C. B. Comstock. Washington. 1880.
Annual Reports of the Board of Water Commissioners of Manchester, N. H. Manchester. 1873 and 1875.
Description of a Hydraulic Pontoon Dock, invented by J. W. Nystrom. St. Petersburg. 1859.
Annual Reports of the Lowell Water Board. Lowell, Mass. 1873 and 1878.
A System of National Defense and Establishing National Foundries. 1840.
Report of the City Engineer of Providence for 1874.
Description of Iron Suspension Bridges at Bangor, Conway, &c., &c. London. 1824.
Bulletin of the Proceedings of the National Institution for Promotion of Science. Washington. 1841.
Communication to the Board of Aldermen of New York by the President of the Trustees of the New York and Brooklyn Bridge. Brooklyn. 1876.
Engineers' Report of the New York City Central Underground Railway. New York. 1869.
Henry's Patent Improved Method of Riveting Boiler Plates.
Survey of the Alleghany River. 1838.
Annual Report of the Chief of Engineer's U. S. A. for 1870.
On Economy of Fuel and the Consumption of Smoke. S. Kneeland. Boston. 1867.
Cases Relating to Telegraphs and Telegrams in American, Canadian and English Courts. Rochester, N. Y. 1866.
Survey of Newark Bay. 1839.
Report of the Chief Engineer of the Charlestown Water Works. Boston. 1865.
Report of the Water Commissioners of Peekskill, N. Y. 1877.
Physics and Hydraulics of the Mississippi River. James B. Eads. New Orleans, La. 1876.
Memoir of the St. Joseph Bridge. Detroit, Mich.
Specifications for an Office Building for the Northern Central Railway Company. Jos. M. Wilson. Philadelphia. 1875.
Ship Building in America. John Roach.
Report on Tests of Eight Oils. J. H. Coleman. Hoboken, N. J. 1877.
Report of the Corporators of the Boston. Hoosac Tunnel and Western Rai road. Boston. 1875.
Civil Engineering, Public Works, and Architecture. Wm Watson. Washington. 1875.
Tabulated Results compiled from Annual Reports of Railroad, Passenger, Canal and Telegraph Companies of Pennsylvania. Harrisburg. 1875, 1876.
A Short Treatise on the Designing and Construction of Geering and Mill Work. New York. 1873.
Annual Report of the Lake Shore and Michigan Southern Railroad. Cleveland. 1873.
Preliminary Report of the Honduras Inter-Oceanic Railway. E. G. Squier. New York. 1854.
Address of Mr. J. B. Eads before the Congressional Committee on Inter-Oceanic Canals in Reply to Count De Lesseps. 1880.
Address before the American Association for the Advancement of Science. A. Hall. Cambridge. 1880.
Correspondence between the business Men of New Orleans and James B. Eads.
Officers, Members and Rules of the American Institute of Mining Engineers.
Safe and Rapid Mode of Tunneling the Hudson. O. B. Dowd. New York.
Argument of Wm. Orton on the Postal Telegraph Bill. New York. 1874.
Annual Report of the Silk Association of America. New York. 1875.
Proposed Union of the Telegraph and Postal Systems. Cambridge. 1869.
Report of the Alabama and Chattanooga Railroad. T. G. Smith. Troy. 1871.
Report of the Committee on Foreign Affairs. Washington. 1876.
Survey of the Harbor of New Haven, 1839.
An Improved System of Cornish Pit Work. E. Daggett. 1879.
Prospectus of the American Steam Boiler and Accident Insurance Company. New York. 1866.
Annual Report upon the Improvement of the Mouth of the Mississippi. Capt. C. W. Howell. Washington. 1873.
Report on the Mississippi Jetties. J. B. Eads. New York. 1876.
Review of the Report of the Mississippi Jetties. J. B. Eads. 1878.
Report on the Grigg's Spark Arrester and Consumer. A. Firth. Pawtucket. 1875.
Argument of the National Association of Bar Iron Manufacturers against any Reduction of Present Duties on Iron. Philadelphia. 1872.
The Panama Ship Canal and Inter-Oceanic Ship Railway Projects. J. M. Goodwin. Cleveland. 1880.
Preliminary Report of the Committee on the Judiciary of the Senate of Pennsylvania on the Difficulties in the Coal Regions.
Report on the Metallurgy of Lead, Silver Copper and Zinc. H. Painter. Washington. 1875.
An Analysis of the Steel Cable Wire of the East River Suspension Bridge. A. Hill. New York. 1877.
Sewerage and Sewage of the City of New York. C. H. Haswell. New York. 1877.
An Analysis of the Corporation of the City of New York. New York. 1854.
A Review of recent Telegraphic Legislation in Canada. London. 1875.
A Discourse on the Atlantic Telegraph. Rev. Dr. Copp. Boston. 1868.
A Letter to the Postmaster-General Reviewing the Recommendations of his Annual Report in favor of a Postal Telegraph.
A Practical and Reliable Apparatus for Removing Scale in Boilers and Preventing its Formation. Philadelphia. 1866.
Report on the Iron Smelting Coals of Southern Indiana. J. W. Foster. Pittsburg. 1871.
Report of the Inspection of the South Pass Improvement. Gen. C. B. Comstock. Washington. 1876.
Annual Report of the Lake Shore and Michigan Southern Railroad Company. Cleveland. 1875, 1876 and 1878.

Annual Report upon the Improvement of the Tennessee Rivers. W. R. King. Washington. 1878.
Speech on Harbor Defenses. Hon. R. F. Stockton. Washington. 1852.
Report of the Chief Engineer of the Kansas City Water-Works. Kansas City. 1875.
Proceedings of the Convention of the American Pig Iron Manufacturers' Association. Philadelphia. 1872.
Review of the Case of the Free Bridge between Boston and Charlestown. Boston. 1827.
Statutes of New York and Canada in Relation to the Bridge across the Niagara River. Buffalo. 1858.
An Answer to a Pamphlet entitled "Considerations on the Public Expediency of a Bridge from one Part of Boston to the Other." Boston. 1806.
Report of Proceedings of the Board of State House Commissioners. Indianapolis, Ind.
Report on Blasting Operations at Lime Point, California. Col. G. H. Mendell. Washington. 1868.
A Synopsis of the Patent Laws of Various Countries. A. Tolhausen. London. 1868.
Argument of Franklin B. Gowen, Esq., before the Joint Committee of the Legislature of Pennsylvania. Philadelphia. 1875.
Annual Report of the City Engineer of Boston. Boston. 1881.
Annual Report of the Columbia Oil Company. Pittsburg. 1881.
Appendix to the History of the Atlantic Telegraph. H. M. Field. New York. 1867.
Ships' Compasses, Including the Subjects of Binnacles and Swinging Ship. Washington. 1869.
Preliminary Report upon the Iron and Steel Industries of the United States. J. M. Swank. Philadelphia. 1881.
The Relation of the Government to the Telegraph. D. A. Wells. New York. 1873.
Report of the Investigating Committee of the Pennsylvania Railroad Company. Philadelphia. 1874.
Surveys of the Harbors of New Buffalo and Twenty-Mile Creek. 1838.
Argument by Henry W. Muzzey before the Legislative Committee on Harbors. Cambridge. 1879.
Report of the Northern Railway and Coal Company. New York. 1865.
Report on the Ashcroft Furnace-Doors and Grate-Bars. Washington. 1878.
Argument before the U. S. Commissioners at the Charletown Navy Yard. W. W. Wieldon. Charlestown. 1869.
Pittsburg and Alleghany in the Centennial Year. G. H Thurston. Pittsburg. 1876.
Report on the Military and Naval Defenses of the United States. 1840.
The Great National Highway between the Missouri River and California. Chicago. 1863.
Report of the National Association of Bar Iron Manufacturers. Philadelphia. 1872.
Annual Report of the Chief Engineer of the St. Joseph Bridge. 1872.
Notes on Public Works in the United States. Sir Charles Hartley.
Prospectus of the Valley Railroad Company. Cleveland. 1874.
Report of the Chief Engineer on the Unfinished Portion of the Northern Pacific Railroad. New York. 1874.
Report of the Chief Engineer of the Camden Water Works. Camden, N. J. 1873.
Report of the Engineer of the Illinois and St. Louis Bridge. St. Louis. 1871.
Annual Report of the Department of Public Works of Chicago. Chicago. 1873.
Additional Chapters, with Appendix, to the Second Edition of the Atlantic Telegraph. H. M. Field. New York. 1867.
Proceedings of the American Pig Iron Manufacturers' Association. Philadelphia. 1873.
Plates of Keeper's Dwelling for a First Order Light House.
Plates of First Order Light House on Fowey Rocks, Fla.
Plates of Light Keeper's Dwelling.
Plates of Light House for Fort Ripley Shoal, Charleston Harbor, S. C.
Plates of Screw Pile Light Houses for Thomas Point Shoal and Port Tobacco Flats.

LIST OF MEMBERS.

ADDITIONS.

MEMBER.

Date of Election.

BRITTAIN, ALFRED. .....City Surveyor's Office, Montreal, Canada...Nov. 2, 1881.

CHANGES AND CORRECTIONS.

MEMBERS.

ALDRICH, JAMES C.....63 Clark St., Brooklyn, N. Y.

ALDRICH, T. H.....P. O. Box 321, Birmingham, Ala.

BARNARD, A. P .....Care D. Van Nostrand, 23 Murray St., New York City, N. Y.

BRUNER, D. P.....Res. Engineer Pittsburgh and Western R. R., Allegheny, Pa.

DEMPSTER, A.....Stanton and Euclid Aves., Pittsburgh, Pa.

EVANS, WALTON W.....New Rochelle, N. Y.

GOLAY, P..... ..New Orleans and North Eastern R. R., New Orleans, La.

GREENE, DAVID M.....41 First Street, Troy, N. Y.

HARRIS, WILLIAM P.....Supt. Western Div. Chesapeake and Ohio R. R., Huntington, W. Va.

HOUSTON, JOHN.....Chief Engineer La Guira and Caracas and Portocabello and Valencia R. R's, La Guira, Venezuela.

LATROBE, CHARLES H ....10 South St., Baltimore, Md.

LINVILLE, J. H.....Consulting Engineer, 4117 Walnut St., Philadelphia, Pa.

MCKEOWN, THOMAS.....Chief Engineer Marquette and Mackinaw R. R., Marquette, Mich.

MCLAIN, LOUIS R.....Div. Engineer R. & D. Extension Co., Oxford, Ala.

NEILSON, ROBERT.....Gen. Sup't P. & E. Div. P. R. R. and Susquehanna, Shamokin and E. and C. Div's Northern Central Ry., Williamsport, Pa.

OLNEY, L. F.....Middletown, N. Y.

POST, JAMES C.....Capt. of Engineers U. S. A., Charleston, S. C.

SEDGWICK, THOMAS S.....Land Agent A. and P. R. R., New Albuquerque, N. M.

SEYMOUR, CHARLES.....Res. Engineer New York, Chicago and St. Louis R. R., Vermillion, Ohio.

SIMPSON, GEORGE H. . . . . New York, Lackawanna and Western R. R., Dansville, N. Y.

WROTNOWSKI, A. F. . . . . Engineer Harbor Improvements, Vera Cruz, Mexico.

JUNIORS.

ABBOTT, ARTHUR V . . . . . 9 Middagh St., Brooklyn, N. Y.

GILLESPIE, J. L. . . . . Ass't U. S. Engineer, P. O. Box 2127, St. Paul, Minn.

RAYMOND, CHAS. WARD. . . New York Works Hudson Tunnel Construction Co., foot of Morton St., New York City, N. Y.

American Society of Civil Engineers.

PROCEEDINGS.

Vol. VII.—December, 1881.

MINUTES OF MEETINGS.

(Abstract of such as may be of general interest to members.)

OF THE SOCIETY.

December 7th, 1881.—The Society met at 8 p. m., Vice-President Welch in the chair. The appointment was directed of a Committee to make arrangements for the Annual Meeting to take place January 18th, 1882. A discussion by E. Yardley, Member A. S. C. E., upon Quicksand in Excavation, was read by the Secretary, and discussed by members present.

December 21st, 1881.—The Society met at 8 p. m., Vice-President Welch in the chair. A vote upon the recent Railroad Crossing case at Elmira, N. Y., with reference to the hydraulic questions brought forward was read by William R. Hutton, Member A. S. C. E. and discussed by Messrs. Adams, J. P. Davis, Emery, Macdonald, Welch and Worthen.

OF THE BOARD OF DIRECTION.

December 7th, 1881.—Applications were considered. Arrangements for the approaching Annual Meeting were considered.

CONTRIBUTIONS TO THE BUILDING FUND.

By a resolution of the Board of Direction, all contributions to the Building Fund are to be acknowledged, from time to time, by printing lists of the same in the monthly Proceedings of the Society, and in addition to this the names of all those who may subscribe $100 or more are to be regularly enrolled and published in future lists of the Society under the head of Subscribers to the Building Fund, and they will be entitled to receive one copy of the monthly publications, comprising all papers and transactions of the Society, regularly, for life, for each $100 subscribed by them; such copies to be in addition to those which they may be already entitled to if they are Members or Fellows.

The following contributions are acknowledged in addition to those heretofore noted:

Francis J. Cisneros	$500 00
*E. L. Corthell	50 00
Eckley B. Coxe	200 00
James H. Cunningham	100 00
*J. B. Eads	125 00
*Henrique Harris	50 00
†B. D. Hasell	100 00
†J. R. Maxwell	100 00
Prescott, Scott & Co	100 00
E. Prince	20 00
T. E. Sickels	100 00
F. C. Weir	50 00

*In addition to the same amount previously acknowledged.

†Additional subscription to payment previously acknowledged.

MEMOIRS OF DECEASED MEMBERS.

ANDREW KLOMAN, Fellow A. S. C. E.

Died December 19th, 1880.

Andrew Kloman, was born at Treve, Prussia, August 25th, 1827. He was educated in the Free Schools of Germany, but was at an early age engaged at the large Iron Works at Marion-Hûtte, with his father who was the Superintendent of rolls at those Works. His parents both died be-

Note.—Committee to prepare memoir, Charles Macdonald, William Metcalf, John Bogart. The principal facts of interest in the life of Mr. Kloman, as given in this memoir, were obtained from the Iron Age of New York, to which journal the Committee desires to express its acknowledgements.

fore he reached the age of eighteen and he then came to America, landing in New Orleans in December, 1845. He went to Pittsburg in the Spring of 1846, and obtained employment, first in the Novelty Works and afterwards in the Steel Works of Singer, Hartman & Co., where he was entrusted with the responsible duty of finishing and testing steel for wagon springs. In 1853 he went into business in a modest way, erecting a forge, and himself doing the work with the assistance of his elder brother. He gradually developed this into the extensive works afterwards so well know. In particular his peculiar genius showed itself in his abandonment of old methods and his invention of new machinery to meet the requirements of his business.

At a time of growing demand for axles he invented a new method for making the pile from which they were hammered, which consisted of a bundle 1 inch square bars bound closely together with the direction of the fibers alternately reversed. This Kloman axle was very successful.

Mr. Kloman afterwards, in conjunction with Mr. Henry Thipps, built the large mill in Pittsburg, now owned by Wilson, Walker & Co. He here made many improvements in designs for rolled shapes, and in machinery for making them. In 1864 this mill was consolidated with the Cyclops Mill and a stock company was formed under the name of the Union Iron Mills ; Messrs. Andrew and Thomas N. Carnegie, being largely interested. Here Mr. Kloman invented many new devices and machinery, among which were the cold saw and a straightening machine which involved a new mechanical motion. This consisted in shortening and lengthening at will the stroke of a piston driven by a cam movement. Mr. Kloman, although the first to apply the cold saw for cutting iron, did not claim and patent its invention because he stated that he took the idea from seeing European watch-makers cutting small spur wheels out of brass disks by bearing them against rapidly revolving steel disks of the size of a penny.

During the construction of the St. Louis Bridge a reliable coupling was required for the tubes forming arches. It was determined to try wrought-iron but the shape being larger than anything before attempted in this country, it was doubted whether any American mill could produce it. Mr. Kloman, however, agreed to make it and in a short time the rolls were prepared, and the largest rolled shape ever made in this country was successfully produced. Its width in the rolls was about 30 inches.

Mr. Kloman was particularly interested in the manufacture of special shapes and was very successful in this direction. Large additions to the works of the firm were made in 1871. In this year also the Lucy Furnace No. 1, was built under his immediate supervision and it was probably, when finished, the most complete blast furnace built up to that time. He introduced the new feature of regulating the inflow of the blast by the revolutions of the blowing engine, discarding the indications of the pressure gauge, which method is now generally adopted. He also in-

vented a rotary table with cooling boxes for receiving slag from the furnaces and conveying it in convenient form to a proper deposit. He successfully introduced into the Union Iron Mills the universal method for rolling heavy and long bridge plates and he devised an ingenious clutch for reversing the motion of the mill. In 1872, Mr. Kloman, in connection with a number of others, purchased land in the Lake Superior region and built a large charcoal furnace. Although at first successful, this enterprise resulted disastrously, and in 1874, Mr. Kloman was obliged to sell out all his business interests. Although compelled to start financially anew, he did so with no less reputation, but with the commendation of all those who were acquainted with his course in this matter.

Soon after he devised a system for rolling weldless eye bars. The demand for steel bars made by this process became large, and in the year 1878 he leased the Superior Mill in Allegheny City, where he made the tension members for the Glasgow Bridge, the steel work for the new suspended structure of the Niagara River Suspension Bridge, and the steel for the Plattsmouth Bridge.

In 1879 he projected the erection of a mill where he could manufacture steel structural material in a more satisfactory way. In connection with other manufacturers it was decided to erect a new Bessemer Works, and these were in process of rapid construction. Mr. Kloman, however, had suffered much in health during the whole of the year 1879, and his debility became very serious in the fall of 1880. He was confined to his house for about a month, and died on the 19th of December of that year.

Andrew Kloman's life was a continued example of the potency of manly, vigorous effort and indomitable perseverance. Difficulties which would have seemed insurmountable to most men were to him incentives to renewed activity; and when disaster swept away at one stroke the fruits of years of honest toil, he wasted not one moment in vain regrets for the past but energetically began anew the battle of life; determined to make the best use of the abilities with which he had been endowed. His loss has been deeply felt by the very large number of friends and associates who appreciated his constant kindly advice and intelligent co-operation, and who have long known his genial spirit, indomitable energy and great kindness of heart.

HENRY CARTWRIGHT, Member A. S. C. E.,

DIED JUNE 30TH, 1881.

Henry Cartwright was born September 13th, 1823, at Wilmington, Delaware. He became a Member of the American Society of Civil Engineers, September 6th, 1876.

The parents of Mr. Cartwright removed to Philadelphia when he was quite young, and he served in that city his apprenticeship at a manufactory of steam engines, boilers and general machinery. At the age of twenty-one he became connected with the firm of Battin, Dungan & Co., which was engaged in the construction of gas and water works. This firm, while Mr. Cartwright was associated with it, built gas works at Newark, Paterson, Hartford, New Haven, Rochester, Syracuse and many other places. About the year 1850 they built water works at Buffalo, N. Y., where they adopted a stand pipe to relieve the pumping main, which, it is claimed, was its first application in this country. The pumping engines were of the class known as the Cornish Bull Engine and it is stated were the first Cornish engines used in this country for water works.

In 1854 Mr. Cartwright became associated with Gen. Herman Haupt in the original contract for the construction of the Hoosac Tunnel. He resided for several years at North Adams, Mass., and while there, was for some time a member of the Legislature of that State. On the suspension of work on the tunnel, he returned to Philadelphia and became connected with the American Meter Company of Philadelphia and New York, serving as its Vice-President from 1868 to 1875. He then resigned and became interested in the Penn. Gas Coal Company of Philadelphia, which has large mines in Westmoreland County, Pennsylvania. He was successively Director and Treasurer of this Company and was elected its President in the spring of the year, 1881. In June of that year, in the prosecution of his duties as President, and in company with other of its officers he was engaged in an inspection of the mines and properties in its control, and during this tour of inspection he passed, on June 30th, 1881, over the Bells Gap Railroad. The party was pushed up the mountain upon a hand-car. In returning they descended by gravity and had passed over about half the road when the car, while moving rapidly, met with an obstruction left on the track by the employees of a saw mill ; Mr. Cartwright was thrown in front of the car which passed over him, injuring him internally. He did not lose consciousness and was not considered seriously injured, but he gradually failed and at six of the evening of the same day he died.

Mr. Cartwright, at the time of his death, was the Vice-President of the Franklin Institute of Philadelphia, of which institution he had been for many years an active and influential member and manager. In his many varied occupations he exhibited remarkable abilities and peculiar tact, particularly in matters connected with mechanics, upon which his judgment was especially valuable ; while in his personal relations he had secured the friendship and esteem of a large circle of acquaintances whose sincere regret for his loss is heightened by the circumstances under which his useful life was brought to a close.

THE NORMAN MEDAL.

CODE OF RULES FOR ITS AWARD.

I.—Competition for the Norman Medal of the American Society of Civil Engineers shall be restricted to Members of the Society.

II.—There shall be one gold medal, and only one, struck for each and every fiscal year of the Society, and awarded as hereinafter provided. The dies therefor shall be with the Superintendent of the United States Mint at Philadelphia, in trust exclusively for the above purpose. Such Medal shall be of a cost equal to the annual interest received upon $1 000 of the Consolidated Stock of the City of New York, Certificate No. 179, of the additional new Croton Aqueduct Stock of the City of New York, authorized by an Act of the Legislature of the State of New York, Chap. 230, passed April 15th, 1870, dated November 17th, 1873, now held in trust by the Treasurer of this Society, and so held solely for this purpose, and shall be executed upon his order.

III.—All original papers presented to the Society by members of any class, during the year for which the medal is awarded, shall be open to the awards, provided that such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been presented to the Society in any previous year.

IV.—The Board of Censors to award the Medal shall consist of three members of the Society, to be designated by the Board of Direction. The Secretary of the Society shall act as Secretary to the Board of Censors.

V.—The medal shall be awarded to such paper as the said Board shall judge to be worthy of special commendation for its merits as a contribution to Engineering Science, not merely relatively as compared with others presented during the same year, but as exhibiting the science, talent or industry displayed in the consideration of the subject treated of, and for the good which may be expected to result from the discussion and the inquiry.

VI.—In case no paper presented during the year shall be deemed of sufficient value to receive an award, the amount of the interest of the fund for that year shall be expended by the Board of Direction in the purchase of books, to be offered as a premium for the second best paper in the next year in which more than one paper of sufficient value may be presented.

VII.—The medal year shall terminate on the first day of August, and the award shall be announced at the Annual Meeting.

VIII.—The Treasurer of this Society shall cause the medal to be prepared and delivered to, or deposited to the order of, the successful competitor, within two months after the Annual Meeting at which the same shall have been awarded.

ADDITIONS TO

LIBRARY AND MUSEUM.

From Charles A. Allen, Worcester, Mass. :

Report on Rebuilding the Lynde Brook Dam.

A complete history of the Worcester Water Works from 1722 to 1877. Worcester. 1878.

Report of the Committee on Additional Supply of Water for City of Worcester. 1881.

A Report upon the possibility of utilizing the Sewage of City of Worcester. 1873.

A complete set of City Documents, containing reports of Mayor, Chief Engineer, City Treasurer, Committees on Finance, and the Several City Officers of the City of Worcester from 1848 to 1881.

From American Academy of Arts and Sciences, Boston :

Proceedings. New Series. Vol. VIII. Whole Series. Vol. XVI. Part 2. From Feb. 1881 to June, 1881.

From American Institute of Mining Engineers, T. M. Drown, Secretary, Easton, Pa. :

The Carbonic Acid Gas Process at the Kehley Rim Colliery Fire. H. M. Chance.

Burnishing and Ductilizing Steel. Jacob Reese.

Proceedings of the Virginia Meeting. May. 1881.

Ore Dressing and Smelting at Pribram, Bohemia. Ellis Clark, Jr.

Brazos Coal Field. Texas. Chas. A. Ashburner.

The Hydrometallurgy of Copper, and its Separation from the Precious Metals. T. S. Hunt.

The Whitewell Firebrick Hot-Blast Stove, and its recent Improvements. F. W. Gordon.

Coal Washing. S. Stutz.

New Method of Mapping the Anthracite Coal Fields of Pennsylvania. Chas. A. Ashburner.

Investigations on the Ore Knob Copper Process. T. Egleston.

Notes on Gold Mill Construction. A. J. Bowie, Jr.

Chemical Methods for Analyzing Rail-Steel. Magnus Troilius.

Manganese Determination in Steel. W. Kent.

Blast Furnace Hearths and Linings. John Birkinbine.

The Rich Hill Iron Ores. E. P. Dewey.

Notes on the Hard Splint Coal of the Kanawha Valley. S. M. Buck.

An Analysis of the Casualties in the Anthracite Coal Mines, from 1871 to 1880. H. M. Chance.

Relations of the Graphite Deposits of Chester County, Pa., to the Geology of the Rocks containing them. Prof. P. Frazer.

On the Solution of Pig Iron and Steel for the Determination of Phosphorus. T. M. Drown.

A Volumetric Estimation of Manganese in Pig Iron and Steel. F. H. Williams.

Note on Black Band Iron Ore in West Virginia. S. B. Sharpless,

The Electrolytic Determination of Copper and the Formation and Composition of So-called Allotropic Copper. J. B. Mackintosh.

Memoranda on the Analysis of Statistics. A. W. Hale.

Discussion on Steel Rails. C. P. Sandberg.

From American Iron and Steel Association, James M. Swank, Secretary, Philadelphia :

Annual Report, containing Statistics of the American Iron Trade to January 1, 1881, and a Review of the present condition of the Iron Industry in Foreign Countries. James M. Swank, Secretary, 1881.

From Robert Ballard, Rockhampton, Queensland, Australia :

Annual Report of the Commissioner of Queensland Railways for 1881. Brisbane. 1881.

From Robert Briggs, Philadelphia :

The Properties of Air relating to Ventilation and Heating. Robert Briggs, C. E. (*Copies for distribution.*)

From the Bureau of Education, Washington, D. C.:

Circulars of Information of the Bureau of Education. Nos. 4, 5 and 6. 1880.

From J. J. R. Croes, New York:

The Public and District Sewers of Denver. H. C. Lowrie. Denver. 1881.

From the Commissioners of the Second Geological Survey of Pennsylvania, W. A. Ingham, Secretary, Harrisburg :

The Geology of the Oil Regions of Warren, Venango, Clarion and Butler Counties, including Surveys of the Garland and Panama Conglomerates in Warren and Crawford, and in Chautauqua County, New York. John F. Carll. Harrisburg. 1880.

The Geology of McKean County and its connection with that of Cameron, Elk and Forrest. Chas. A. Ashburner. Harrisburg. 1880.

The Geology of Clinton County. Part I.

The Geology of Clinton County. A Special Study of the Carboniferous and Devonian Strata around the West Branch of the Susquehana River. H. Martyn Chance. Harrisburg. 1880.

Description of the Coal Flora of the Carboniferous Formation in Pennsylvania and throughout the United States. Vols. I and II.

Report of Progress in Armstrong County. W. G. Platt. Harrisburg. 1880.

From Allen Cunningham, R. E., London :

Hydraulic Experiments. Capt. Allen Cunningham. Roorkee, India. 1880.

Vol. I. Text.

Vol. II Tables, Part 1. Detailed Tables, Part 2. Abstract Tables.

Vol. III. Plates.

From G. Howard Ellers, Chief Engineer Sewerage Department, Chicago :
Annual Report on the General Sewerage System of Chicago for 1880.

From the Engineers Society of Western Pennsylvania, Pittsburgh :
Annual Reports. January 18, 1881.
Address of the Retiring President. Wm. Metcalf.
Notes of a Trip through the James River Valley. J. D. Weeks.
Discussion by Reuben Miller, B. F. Jones, Wm. Kent, Jos. D Weeks, W. F. Zimmerman, S. Wickersham and T. P. Roberts.
Pittsburgh's Sewer System. G. H. Brown.
Discussions by Alex. Dempster, Chas. Davis, Wm Kent, J. J. R. Croes, T. P. Roberts.
Dam of the Montaubry Reservoir. Lieut. F. A. Mahan.

Danks Puddling Furnace. Samuel Adams.
Discussions on "The Basic Dephosphorizing Process. What it is and what may be expected from it," by James Park, Jacob Reese, Charles Parkin, Wm. Metcalf.
Kloman Eulogy. James Parks, Jr., and James Hemphill, Committee.

From Albert Fink, New York :
Proceedings of the Joint Executive Committee from Dec. 18. 1878, to Dec. 18, 1879.
Proceedings Joint Executive Committee of Railroads for 1880.
The Railroad War. Editorial from *New York Herald*, August 3, 1881.
Competition, Combination or Regulation? Editorial from *New York Times*, August 3, 1881.
Why Railroad Tariffs are not Maintained. Albert Fink in *Produce Exchange Bulletin*, July 22, 1881.

From C. E. Fowler, New Haven, Ct. :
Report of the Special Investigation Committee as to the purchase of the New Haven Water Works. New Haven. 1881. (2 copies.)

From Sir John Hawkshaw, F. R. S., London :
Report of the Committee appointed to consider the question of Wind Pressure on Railway Structures. London. 1881.

From Harrison Bros. & Co., Philadelphia, through Charles Neilson, M. Am. Soc. C. E., New York :
History of the Mexican Railway. Gustavo Baz and E. L. Gallo. Mexico. 1876.

From John Hopkin's University, Baltimore, Md. :
Register of the University. 1880-81.

From Institution of Civil Engineers, James Forrest, Secretary, London :
Minutes of Proceedings, Vol. LXIV. 1880-81.
On the Comparative Endurance of Iron and Mild Steel when exposed to corrosive influences. David Philips.
The Actual Lateral Pressure of Earthwork. Benjamin Baker.
The Tide Gauge, Tidal Harmonic Analyzer and Tide Predicter. Sir William Thomson.
Description of a Bucket Dredger in use at the Hull Docks. Robert Apsland Marillier

From Iron and Steel Institute, London :
Journal of the Institute, No. 1, 1881.

From John A. Judson, Newport, R. I.:
Annual Reports of the Sanitary Protection Association of Newport, R. I., for 1880-81.

From John Kennedy, Montreal, Canada :
Annual Report of the Harbor Commissioners of Montreal for 1880. (2 copies.)

From William B. Knight, Kansas City, Mo. :
Report of the Commissioner on Water Works of the City of Kansas. April 16. 1881.

From C. H. Latrobe, Baltimore, Md.:
A Report upon a Plan of Sewerage for Baltimore City and its probable cost. C. H. Latrobe. Baltimore. 1881.

From Miller, Metcalf & Parkin, Pittsburgh :
The Treatment of Steel. Miller, Metcalf & Parkin. Pittsburgh. 1881.

From Mining Institute of Scotland, James Gilchrist, Secretary, Hamilton, Scotland :
Transactions, General Meeting, June 1881. Vol. III., No. 3. Index to Vols. I. and II.

From Isaac Newton, Chief Engineer Croton Aqueduct, New York :
Annual Report of the Croton Aqueduct for 1852, 1861, 1862 to 1868 inclusive.

From New York Meteorological Observatory, Daniel Draper, Director, New York :
Abstract of Registers of Self-recording Instruments. June, 1881.

From North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne :
Transactions. March, April, May and June, 1881.

From E. Pontzen, Paris, France :
Neber.das Technische Schul und Vereinswesen Frankreichs. Wilhelm von Nördling. Wien. 1881.

From Royal United Service Institution, London :
List of Members. April 15, 1881.

From L. Y. Schermerhorn, Milwaukee, Wis. :
The Water-Jet as an aid to Engineering Construction. L. Y. Schermerhorn, C. E. Washington. 1881.

From T. Guilford Smith, Buffalo, N. Y.:
Eighth, Ninth, Tenth and Eleventh Annual Reports of the Buffalo Park Commissioners. August, 1881.
The Past and Future of Buffalo. Henry Martin. Buffalo, 1881.
Report of the Receivers of the Philadelphia and Reading Railroad Company and of the Philadelphia and Reading Coal and Iron Company for the year ending November 30, 1880.
The Railway Problem. Address of Mr. Franklin B. Gowen on the Position which the City of Philadelphia should occupy to the Commonwealth of Pennsylvania to its transportation times, and to the Railway problem of the day. June 16, 1881.

From the U. S. Coast and Geodetic Survey, Washington :
Deep Sea Sounding and Dredging. A description and discussion of the methods and appliances used on board of the steamer

Blake, Lieut. Com. Charles D. Sigsber, U. S. N. Washington. 1880.

Astronomical and Meteorological Observations made during the year 1876. Rear Admiral C. H. Davis, U. S. N., Supt. Washington. 1880

From E. B. Van Winkle, New York:

Report on the Drainage of the 23d 24th Wards, New York City. E B. Van Winkle. Documents No. 88, Department Public Parks. 1881.

Boden und Grundwasser in ipren beziehungen zu Cholera und Typhus. Erovlederung aui Rudolph Virchow's Hygienische Studie "Canalisation oder Abfuhr." Max. v. Pettenkrofer. München. 1869.

Proposals for Constructing Sewers and Appurtenances in One Hundred and Forty-sixth street, between Third Avenue and Brook avenue, with branches in Willis avenue between One Hundred and Forty-sixth and One Hundred and Forty-seventh streets, and in Courtland avenue, between Third avenue and One Hundred and Fifty-first street.

Proposals for Estimates for Macadamizing Broadway, in the 24th Ward, and also Building Culverts, Laying Drain Pipe, and Paving Gutters therein, from the road leading to Kingsbridge Station, to a point 300 feet north of the Van Courtland's Lane.

Proposals for Constructing Sewers and Appurtenances in One Hundred and Thirty-ninth street, from Third avenue to the Summit between Alexander and Willis avenues with branches in Alexander avenue between One Hundred and Thirty-ninth and One Hundred and Fortieth streets.

Proposals for Estimates for Constructing a Sewer and Appurtenances in One Hundred and Forty-first street, between Alexander and Willis avenues, with branches in Willis and Alexander avenues, between One Hundred and Forty-first and One Hundred and Fortieth streets.

Proposals for Constructing Sewers and Appurtenances in One Hundred and Forty-fifth and One Hundred and Forty-fourth streets, between Third and Brook avenues, and in One Hunred and Forty-third street, between Alexander and Brook avenues, with branches in Willis avenue, between One Hundred and Forty-sixth and One Hundred and Forty-second streets, and in Alexander avenue between One Hundred and Forty-third and One Hundred and Forty-second streets.

From Elwyn Waller, New York:

Report on Croton Water. Elwyn Waller, Ph. D. New York. 1881. (2 copies.)

From A. S. C. Wurtele, Albany, N. Y.:

Report of the Directors of the Illinois Central Railroad Company for year ending December 31, 1868.

Annals of the Dudley Observatory. Vol. II. Albany. 1871.

A Description of the Canals and Railroads of the United States. H. S. Tanner, New York. 1840.

Guide for the Pennsylvania Railroad Company, with an extensive map including the entire route. Philadelphia. 1855.

Reports of the Meteorological Magnet and other Observatories of the Dominion of Canada. Ottawa. 1877.

Report of the Liverpool and Manchester Railway on the Comparative Merits of Locomotive and fixed Engines. James Walker. Philadelphia. 1831.

Observations on the Comparative Merits of Locomotive and fixed Engines, as applied to Railways. Robt. Stephenson and Joseph Locke. Philadelphia. 1831.

An Account of the Liverpool and Manchester Railway. Henry Booth. Philadelphia. 1831.

Report of the Chief Engineer of Public Works on the Progress of Canal Enlargement between Lake Erie and Montreal. Ottawa. 1877.

Report on the proposed Chesapeake Bay and Potomac River Tide-Water Canal, from Washington to Annapolis. S. H. Sweet. Albany. 1866.

Report of the Condition of the West Wisconsin Railway Company. New York. 1876.

Reports of the Superintendent of the Montreal Water Works for 1875, 1876 and 1877.

A Statement of the Property, Condition and Resources of the Reciprocity Mining Company. New York. 1874.

Charter of the Cherry Valley and Mohawk River Railroad. Albany. 1864.

Report of the President and Directors of the Ohio and Mississippi Railway. St. Louis. 1873.

Annual Report and Statement of the Condition of Affairs of the La Crosse and Milwaukee Railroad. Albany. 1859.

Report of the Chief Engineer of the Placerville and Sacramento Valley Railroad of California. San Francisco. 1863.

Report on Tidal Investigations in Mystic River and Pond. Boston. 1861.

Proceedings of the Railroad Convention held at the St. Nicholas Hotel in New York. New York. 1855.

Minutes of the Grand International Division of the Brotherhood of Locomotive Engineers, at their Annual Session held at Boston, Mass. Rochester, N. Y. 1866.

Report of the Utica and Schenectady, Syracuse and Utica, Auburn and Syracuse, Auburn and Rochester, Tonawanda and Buffalo, and the Utica Railroad Companies. Nov. 15, 1842.

Report of the Grand Trunk Railway Company of Canada. London. 1867.

Report of the Select Committee to which was referred the Petitions for aid to the Albany and Susquehanna Railroad Company. Albany. 1860.

Annual Report of the Brockville and Ottawa Railway Company. Montreal. 1868.

Report of the Chief Engineer of the N. Y. & O. Midland Railroad. A. C. Powell. Norwich, N. Y. 1867.

The Pacific Railway and the Claims of Saint John, N. B., to be the Atlantic Terminus. Read before the Mechanics' Institute of Saint John, February 7, 1859. T. T. Smith, C. E.

Philosophy of Railroads. T. C. Keefer, C. E. Montreal. 1853.

Report of the Northern Railway of Canada. Toronto, Ont. 1873.

Lease of the Saratoga and Hudson River Railroad Company to the New York Central Railroad Company. Albany. 1867.

Report of the Supply of Water of the City of Hamilton. Montreal. 1856.

Report of the Supply of Water, Drainage and

Improvement of the City of Ottawa. Ottawa. 1861.

Act of Incorporation and Reports of the Rochester Water Works. New York. 1870.

Reports of the Water Commissioners to the Common Council of the City of Albany. Albany. 1866.

Specifications for the Excavation, Masonry, Crib Work, Bridging and Fencing, for the Tail Race of the Montreal Water Works.

The Water Supply and the Hydraulic Company Question. Montreal. 1868.

Rapport Annuel du Surintendant de L'Aqueduc de Montreal. Montreal, 1863 and 1864.

Annual Report of the Superintendent of the Montreal Water Works for the year ending January, 1864, 1866, 1868, 1869, 1870, 1871, 1872, 1873, 1874.

Report of the Montreal Water Works. By Walter Shanly and James B. Francis. Montreal. 1868.

Report of the Montreal Water Works. Wm. J. McAlpine. Montreal. 1869.

Report of the Montreal Water Works. By Walter Shanly, T. C. Keefer and James B. Francis. Reviewed by Wm. Rodden, Alderman. Montreal. 1869.

Report of the City Surveyor of the City of Montreal, during the years 1864, 1865, 1867, 1869, 1872.

Communicaton from State Officers, together with Documents, Remarks and Opinions Relating to Repairs of the New York State Canals. Albany. 1865.

Report of the Minority of the Select Committee on the Pro Rata Freight Bill. Albany. 1860.

Remarks of Thomas M. Monroe before the National Board of Trade, at its meeting in December, 1868, in the City of Cincunati.

An Act to Authorize the Construction of Certain Bridges, and to Establish them as Post Roads.

Address to the American Association for the Advancement of Science. Thomas Sterry Hunt. Salem. 1871.

Information for Emigrants. Province of Manitoba and Northwest Territory of the Dominion of Canada.

Report of the Water Commissioners of the Common Council of Albany. Albany, 1879.

The Pro Rata Question. What is the True Policy of the State of New York? Discussed by J. W. Brooks. Albany. 1860.

Report and Estimate Cost of the New York and Albany Railroad. C. W. Wentz. Albany. 1867.

Statutes of Canada: An Act for the Incorporation of a Company to Construct a Railroad between Bytown and Prescot (May 10, 1850). Bytown. 1852.

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